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SYSTEM STUDY Final Report (Martin Marietta
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To: National Aeronautics and Space Administration
John F. Kennedy Space Center
Kennedy Space Center, Florida 32899

Attn: Mr. Robert M. Kernan, AD-PR022

Subj: Contract NAS10-8902, KSC Launch Site
Multi-Use Mission Support Equipment Study
(MMSE)

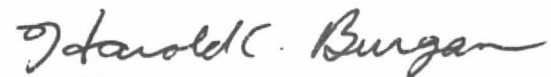
Ref: (a) Contract NAS10-8902, Para. 6.0, Attachment 1

Encl: (1) Payload Transportation Study - Final Report
(1 copy)

The Payload Transportation System Study (Final Report), Enclosure (1), is transmitted in compliance with the requirements of the subject contract.

Very truly yours,

MARTIN MARIETTA CORPORATION



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Distribution: Attached List

PAYLOAD TRANSPORTATION
SYSTEM STUDY

Prepared For:
National Aeronautics and Space Administration
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FOREWORD

This document contains the Final Report of the Launch Site Multi-Use Mission Support Equipment (MMSE) Study, Payload Transportation System Task, being performed under Contract NAS10-8902 for the John F. Kennedy Space Center by the Martin Marietta Corporation.

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ACRONYMS AND ABBREVIATIONS

A	- Automated Payload	HQS	- Headquarters
A&A	- Advertise and Award	I/F	- Interface
A/C	- Aircraft	Insp.	- Inspection
AMPS	- Atmospheric, Magnetospheric & Plasmas in Space.	IUS	- Interim Upper Stage
APU	- Auxiliary Power Unit	JSC	- Johnson Space Center
ARC	- Ames Research Center	JPL	- Jet Propulsion Lab
Auto	- Automated Payload	K	- Thousand
Auto/IUS	- Automated Payload/Interim Upper Stage	KSC	- Kennedy Space Center
BESS	- Biomedical Experiment Scientific Satellite	LaRC	- Langley Research Center
CFM	- Cubic feet per minute	LDEF	- Long Duration Exposure Facility
CG	- Center of Gravity	LeRC	- Lewis Research Center
CN	- Container	LHA	- Large System, Hard Container, Air Transport
Com.Ops.	- Complexity of Operations	LHR	- Large System, Hard Container, Road Transport
CR	- Carrier	LSA	- Large System, Soft Container, Air Transport
DDT&E	- Design, Development, Test and Engineering	LSR	- Large System, Soft Container, Road Transport
Ded.	- Dedicated	MHA	- Medium System, Hard Container, Air Transport
Del.	- Delivery (of payload to orbit)	MHR	- Medium System, Hard Container, Road Transport
Des.	- Design	MSA	- Medium System, Soft Container, Air Transport
DFRC	- Dreyden Flight Research Center	MSFC	- Marshall Space Flight Center
DN	- Down	MSR	- Medium System, Soft Container, Road Transport
EAFB	- Edwards Air Force Base (now DFRC)	M/P	- Module and Pallet (Spacelab)
ECS	- Environmental Control System	MMSE	- Multi-use Mission Support Equipment
ECU	- Environmental Control Unit	N/A	- Not Applicable
ESA	- European Space Agency	OFT	- Orbiter Flight Test
EST.	- Estimate	OA Comp	- Operational Complexity
Expt.	- Experiment	P/L	- Payload
FB	- Flatbed	Reefer	- Refrigerated Unit
FSS	- Flight Support System (GSFC)	Ret	- Retrieval (of payload from orbit)
Gen	- Generator	RH	- Relative Humidity
GFP	- Government Furnished Property		
GSE	- Ground Support Equipment		
GSFC	- Goddard Space Flight Center		
H	- Hard (container)		
Hw	- Hardware		

ACRONYMS AND ABBREVIATIONS (Continued)

ROM - Rough Order of Magnitude
SHA - Small System, Hard Container, Air
Transport
SHR - Small System, Hard Container, Road
Transport
S/L - Spacelab
SO - Soft (Container)
Spec - Specification, or Specialist
SSA - Small System, Soft Container, Air
Transport
SSPD - Shuttle System Payload Descriptions
SSR - Small System, Soft Container, Road
Transport

STS - Shuttle Transportation System
Supt - Support
TAB - Tabulation
TEMS - Transporter Environment Monitor
System
TBD - To Be Determined
T-MMSE - Transportation - Multi-use Mission
Support Equipment
TR - Trace
Vac - Vacuum
WF - Weighting Factor

STUDY OBJECTIVES

The purpose of the Payload Transportation System Study was to define a standard size set of Shuttle payload transportation equipment that will: 1) substantially reduce the cost of payload transportation, and 2) accommodate a wide range of payloads with minimum impact on payload design.

The system was designed to accommodate payload shipments between the Level IV payload integration sites and the launch site during the calendar years 1979 - 1982. In addition to defining Transportation Multi-Use Mission Support Equipment (T-MMSE) the study also defined the mode of travel, prime movers and ancillary equipment required in the transportation process.

Consistent with the STS goals of low cost and the use of standardized interfaces, the transportation system is designed to commercial grade standards and uses the payload flight mounting interfaces for transportation.

The overall objectives of this study were to develop the technical, cost and programmatic data required to permit selection of a baseline system of MMSE for intersite movement of Shuttle payloads in the calendar years 1979 - 1982 and to define a standard size, transportation system that achieves a high degree of commonality and cost effectivity.

STUDY OBJECTIVES

- o DEVELOP TECHNICAL, COST AND PROGRAMMATIC DATA REQUIRED TO PERMIT SELECTION OF A BASELINE SYSTEM OF MMSE FOR INTERSITE TRANSPORTATION OF SHUTTLE PAYLOADS IN THE CALENDAR YEARS 1979-1982
- o DEFINE A STANDARD-SIZE TRANSPORTATION SYSTEM WHICH ACHIEVES A HIGH DEGREE OF COMMONALITY AND COST EFFECTIVITY

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SCOPE

The following major tasks are included in the study scope:

- (A) Evaluation of previous transportation studies for applicability to this study.
- (B) Analysis of payload transportation requirements for the 1979-1982 mission model; cost effectivity analyses included the 1983-1991 traffic model for statistical data only. The Mariner series spacecraft was also included.
- (C) Definition of candidate transportation system concepts to meet these requirements.
- (D) Detailed evaluation and development of selected systems concepts including conceptual design analyses, interface definitions, costs and schedules.

Payload operations included in the following two phases were assessed during the study. The first phase commences with delivery of transportation equipment to a Level-IV integration site in preparation for loading payloads for shipment to the launch site and ends with unloading of the payload at the appropriate launch site facility. The second phase commences with delivery of the transportation equipment to the landing site in preparation for loading payloads for shipment to the Level-IV integration site and ends with unloading of the payloads at the Level-IV integration site.

SCOPE

- o EVALUATE PREVIOUS TRANSPORTATION STUDIES FOR APPLICABILITY
- o ANALYZE PAYLOAD INTERSITE (LEVEL IV SITE ↔ LAUNCH SITE)
TRANSPORTATION REQUIREMENTS FOR THE CALENDAR YEARS 1979-1982
- o DEFINE CANDIDATE TRANSPORTATION SYSTEM CONCEPTS TO MEET THESE
REQUIREMENTS
- o PERFORM DETAILED EVALUATION AND DEVELOPMENT OF SELECTED CONCEPTS
INCLUDING CONCEPTUAL DESIGN ANALYSES, INTERFACE DEFINITION, COSTS
AND SCHEDULES

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GUIDELINES AND ASSUMPTIONS

The key guidelines and assumptions used during the course of the study are listed on the facing chart. Other lower level guidelines and assumptions, which are specific to individual study tasks, are listed as part of the task discussions.

The 13.5 ft height restriction was imposed to ensure system compatibility with road transportation requirements and the maximum capability of the C-5A aircraft. All payloads exceeding this height limitation were considered "outsized" and were not assessed as part of this study.

The only mode of transportation excluded from this study was water. This exclusion was based primarily on the time required to transport via water.

The Guppy and 747 canister were also excluded from consideration due to the uncertainty of their availability.

Restricting Level II and III payload integration to the launch/landing site eliminates the need to transport Spacelab modules or integrated rack/floor assemblies to the Level IV sites. Post-landing deintegration of Spacelab pallet-mounted and rack-mounted experiments at the landing site also eliminates the requirements to transport loaded pallets or racks back to the Level IV sites.

The payload development centers were assumed synonymous with the Level IV payload integration sites.

The use of the December 1975 Esenwein traffic model limits launches to KSC during the 1979 - 1982 period, and results in handling forty-three non-DOD payloads to support thirty-one STS flight. The payload model is summarized on a later chart.

DOD payloads were not considered in the study at DOD request. Flight adapters were ruled out for use in intersite payload transportation to prevent requiring an overwidth (15'-plus) system for all payload shipments.

GUIDELINES AND ASSUMPTIONS

- o ADDRESS STANDARD-SIZE PAYLOADS
(13.5' OVERALL HEIGHT LIMIT, INCLUDING CARRIER AND CONTAINER)
- o ADDRESS AIR, ROAD AND RAIL MODES OF TRANSPORTATION
- o SPACELAB LEVELS II & III INTEGRATION AT KSC
- o LEVEL IV SITES -- ARC, JPL, JSC, LARC, MSFC, GSFC, LERC
- o USE PRELIMINARY ESTIMATE PAYLOAD MODEL DATED 12/15/75, COVERING
1979-1982; ALL LAUNCHES FROM KSC
- o EXCLUDE DOD PAYLOADS
- o DO NOT CONSIDER GUPPY OR 747 CANISTER
- o STRUCTURAL FLIGHT ADAPTERS NOT USED FOR TRANSPORTATION

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DEFINITIONS

Definitions for some of the top-level terms used in the transportation study are presented on the facing chart. Other definitions are as follows:

Ancillary Support Equipment - Support equipment required for transportation but not procured as part of the MMSE, probably rented; for example, cranes, escort vehicles, etc.

Environmental Control System - Equipment provided for control of the payload environment, for example, generators, air conditioners, heaters, dehumidifiers, etc.

Transportation System - The combination of all elements and equipment necessary to achieve transportation of payloads. A single system may utilize a number of transportation modes and a family of various containers and ancillary support equipment. For example, one system could utilize the Spacelab GSE with the C5A aircraft for Spacelab payloads; a small container with a standard tractor for small automatic payloads, and a larger container with the C5A for larger automated payloads. The total of these three would constitute a single system.

DEFINITIONS

TRANSPORTATION SYSTEM - COMBINATION OF ALL ELEMENTS AND EQUIPMENT NECESSARY TO TRANSPORT PAYLOADS

CARRIER - PRIMARY VEHICLE FOR TRANSPORTING PAYLOADS (TRACTOR/TRAILER, AIRCRAFT)

CONTAINER - ENCLOSURE WHICH HOUSES PAYLOAD; CONSISTS OF TRANSPORT PLATFORM AND COVER

COVER - HARD (STRUCTURAL) OR SOFT (NON-STRUCTURAL) CONTAINER TOP

PAYLOAD ADAPTER - PROVIDES ATTACHMENT OF PAYLOAD TO TRANSPORT PLATFORM

PAYLOAD INTEGRATION LEVELS - IV: INSTRUMENT TO SPACECRAFT/PALLET
III: SPACECRAFT/PALLET TO PAYLOAD
II: PAYLOAD TO CARGO
I: CARGO TO ORBITER

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SUMMARY OF STUDY RESULTS

The recommended baseline intersite transportation system is an over-the-road system consisting of two groups of hardware. The small system utilizing standard 8 ft wide, air-ride, climate controlled vans accommodates payloads up to 7.2 ft wide, 7.5 ft high and 20 ft in length. The large system utilizing standard 8 ft wide, air-ride tractors and low-boys accommodates payloads up to 14.3 ft wide, 10.8 ft high and 20 ft. long.

Both systems provide a controlled environment for the payloads while in transit (i.e., cleanliness, temperature, relative humidity and shock and vibration) and are compatible with air transport.

The transportation system can accommodate all of the payloads in the preliminary estimate payload model (1979 - 1982), with the exception of the assembled Long Duration - Exposure Facility (LDEF). The two major restrictions on payload shipments both concern Spacelab hardware: 1) only one pallet segment can be shipped, per system, if the experiments extend to the maximum fifteen-foot diameter of the payload bay; and 2) the traffic analysis does not include use of the large system for transporting integrated rack/floor assemblies. The rack/floor assemblies can be physically accommodated in the large system, but since such shipments were groundruled out, the number of large systems provided was not based on such usage. Additional systems might be required if the groundrule is changed.

The cost for system hardware acquisition (three small and five large systems) and operations through 1982 is estimated to be approximately \$3.5 million.

To support Shuttle flights as now defined the procurement of the large system should begin no later than October, 1977, and the small system by July, 1978.

- BASELINE SYSTEM - ROAD TRANSPORT (AIR COMPATIBLE)
 - SMALL SYSTEM - PAYLOADS TO 7.2' W X 7.5' H X 20' L
 - LARGE SYSTEM - PAYLOADS TO 14.3' W X 10.8' H X 20' L
- SYSTEM PROVIDES CONTROLLED ENVIRONMENT
 - CLEANLINESS
 - TEMP & RH
 - SHOCK/VIBRATION
- SYSTEM ACCOMMODATES ALL PAYLOADS IN MODEL EXCEPT LDEF
 - SPACELAB PALLETS - TWO IF LESS THAN 10.8' HIGH
 - ONE IF MORE THAN 10.8' HIGH
- SYSTEM COST - \$3.5 MILLION
- PHASE B DEFINITION START
 - LARGE SYSTEM - OCTOBER 1977
 - SMALL SYSTEM - JULY 1978

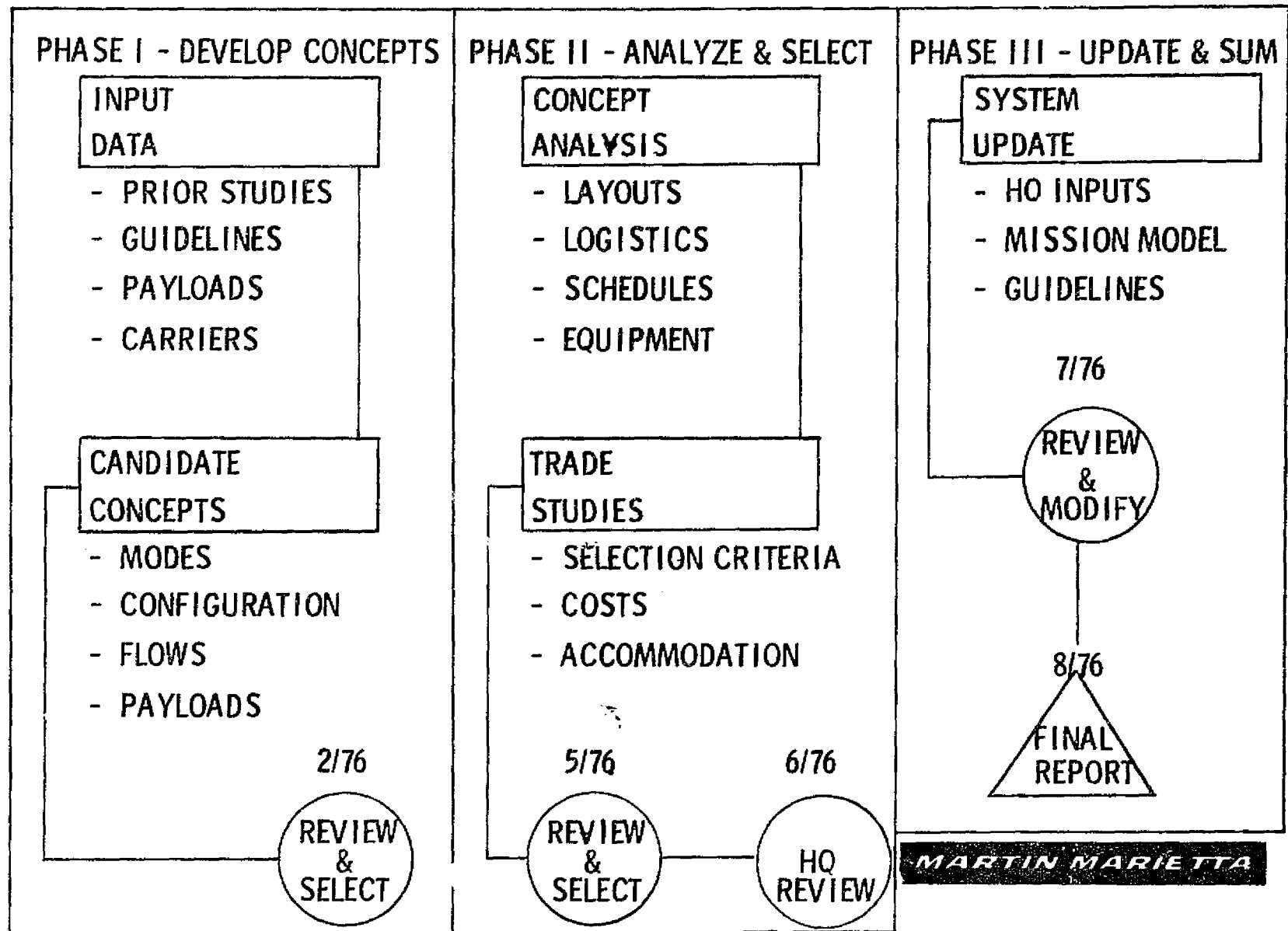
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PAYLOAD TRANSPORTATION SYSTEM - STUDY FLOW

A time phased summary of the study flow logic is shown on the facing chart. During the first phase, candidate transportation system concepts were developed, based on payload requirements through 1982. The concepts included assessment of air, rail and road modes of travel and various techniques for supporting and protecting payloads in transit. A total of thirteen (13) concepts were developed during this phase and two were selected for detailed analysis in Phase II. The detailed analyses included equipment layouts and definition, logistics analysis and functional flows and timelines. Cost data were developed for each hardware and operations element for both concepts, and criteria were developed to aid in selecting the most effective system in terms of cost and payload accommodations.

The final study phase was used to define the engineering requirements of the baseline system hardware, define the interfaces between payloads and the transportation system, to develop an outline of the proposed users handbook, and to update and publish the study results.

PAYLOAD TRANSPORTATION SYSTEM - STUDY FLOW



PRELIMINARY ESTIMATE PAYLOAD MODEL

The payload model used as the basis for payload and Shuttle traffic, and, therefore, payload transportation traffic for the 1979 through 1982 time frame is the Preliminary Estimate Payload Model, dated 15 December 1975. A summary of the model is presented on the facing chart.

The first launch in the model coincides with Orbiter Test Flight #3 in the fourth quarter of 1979. The first launch deploys an automated satellite (Gamma Ray Explorer) and retrieves the first LDEF. The first Spacelab flight is scheduled in the 3rd quarter, 1980 and utilizes both the module and pallets. The first pallet only Spacelab mission is in the 4th quarter, 1980. Excluding DOD traffic, 43 payloads are delivered/retrieved on 31 Shuttle launches.

PRELIMINARY ESTIMATE PAYLOAD MODEL

(G. ESENWEIN, 12/15/75)

YR/QTR PAYLOAD CLASS	79	1980				1981				1982				TOTAL
	4	1	2	3	4	1	2	3	4	1	2	3	4	
AUTOMATED DEPLOY	1	1	1		1		2			3			2	(16)
RETRIEVE						1				2	1			11
DEPLOY/RETRIEVE	1													4
														1
AUTO/IUS DEPLOY (PAYLOAD/IUS)						2/1			2/2	3/2	2/1			(9)
														9/6
SPACELAB MODULE + PALLET				1				2	1	1	2	3	1	(18)
MODULE ONLY						1	1	1			1		1	11
PALLET ONLY					1							1		5
														2
NON-DOD TOTAL	2	1	1	1	2	4	3	3	3	6	7	6	4	43
(DOD TOTAL)	(0)	(0)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(2)	(1)	(1)	(3)	(14)
TOTAL PAYLOADS	2	1	2	2	3	5	4	4	4	8	8	7	7	57
NON-DOD FLIGHTS	1	1	1	1	1	2	2	3	3	3	5	5	3	31
(DOD FLIGHTS)	(0)	(0)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(2)	(1)	(1)	(3)	(14)
TOTAL FLIGHTS	1	1	2	2	2	3	3	4	4	5	6	6	6	45

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REQUIREMENTS

A wide range of requirements were defined as a basis for defining transportation concepts. Previous studies (facing chart) were reviewed for applicability, payload transportation requirements were gathered from the SSPD and personal contact with developers, transportation traffic requirements were developed based on the payload model, carrier data was based on inputs from the military and commercial concerns, and finally functional flows and timelines were generated to identify overall transportation time, personnel and equipment requirements.

The facing chart lists the previous studies which were reviewed and the type of data contained in each which was potentially applicable to this study. Both hardware and operations concepts were reviewed and applicable data was utilized in developing the transportation system for Shuttle payloads.

Each study was reviewed for existing hardware, transport mode which may be applicable to this study effort, timelines which would correlate to our study, cost estimates for manpower or equipment and design data which could be effectively utilized.

PREVIOUS STUDIES

STUDY	APPLICABLE DATA	HARDWARE CONCEPT				OPERATIONAL CONCEPT DATA									
		EXIST HW	XPORT MODE	TIME EST	COST EST	DES DATA	H2O	ROAD	RAIL	AIR	TIME EST	COST EST	OA CONC	COM OPS	DES DATA
SPACELAB TRANS'N			X	X	X	X	X	X	X	X	X	X	X		X
MARINER/VIKING TRANSPORTATION		X	X	X	X	X		X			X		X		X
GSFC INTERIM TRANSPORTATION			X	X	X	X	X	X		X	X	X	X	X	X
GSFC PAYLOAD TRANSPORTATION						X									X
TRAFFIC IMPACT STUDY			X					X	X	X					
747 CARGO STUDY			X	X	X					X			X		X
OUTSIZED CARGO STUDY			X							X		X	X	X	X
KSC SHUTTLE VEHICLE ELEMENTS			X					X		X					X
TRW AF#777 TRANSPORTATION		X	X			X		X		X					X
SO RAIL ENV DATA		X	X		X	X			X		X				X
SO RAIL CUBE DATA		X	X	X	X	X			X		X	X	X	X	X

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PAYLOAD REQUIREMENTS

Payload requirements were based on the SSPD data and supplemented by contact with cognizant personnel. The facing chart is a typical sheet of the data bank. Although data was still missing after personal contact, in the majority of cases enough data was available on which to base conceptual design.

Automated payloads in the model ranged from 3.3 ft to 14 ft in diameter and from 3.3 ft to 30 ft long. Spacelab pallet requirements were worked to the maximum potential size of a loaded pallet, which is 14.3 ft wide x 15 ft high x 9.8 ft long with experiments and weighs up to 9255 lb. Spacelab racks were assumed handled only as singles or doubles with envelopes ranging from about 2 to 4 ft wide x 4.5 ft high x 10 ft long.

The environments the payloads require vary from wide temperature ranges (-46°F to $+170^{\circ}\text{F}$) to the normal of $50-100^{\circ}\text{F}$, relative humidity from 70 to 90% maximum, shock/vibration from 3g to 22.5 g (non-operating) and cleanliness class 5000 to 100,000.

PAYLOAD REQUIREMENTS - DATA BANK (TYPICAL)

MISSION DATE Yr Qr	PAYLOAD	MODE	SSPD DESIG	WEIGHT lb	DIMEN HxWxL ft	ENVIRONMENT			
						TEMP °F	RH %	V/S g's	CLEAN Class
82-1	BESS	DEL	LS-02-A	4000	12.1x12.1x9.5	50-100	TBD	TBD	100K
82-1	LDEF	RET	ST-01-A	14860	14x14x30	41-151	95 Max	5	N/A
82-1	SOLAR MAX	RET	SO-03-A	3388	7x7x15.2	40-131	95 Max	15	5K
82-1	SPACE PROC	M/P	SP-14-S	15243	8.48x14.75x10	50-104	70 Max	4	100K
82-1	GRAVITY PROBE B	DEL	AP-04-A	1430	7.2x7.2x11.8	TBD	TBD	9	5K
82-1	RAD BUDG SAT	DEL	EO-16-A	390	3.3x3.3x3.3	N/A	N/A	N/A	N/A
82-2	ADVANCED TECH LAB	M/P	ST-58-S	3891	8.48x14.75x10	-46-170	95 Max	5	100K
82-2	LUNAR POLAR ORB	IUS	LU-05-A	1858	6.7x6.7x15.6	N/A	N/A	N/A	N/A
82-2	BESS	RET	LS-02-A	4000	12.1x12.1x9.5	50-100	TBD	TBD	100K

MODE LEGEND:

DEL = DELIVERY
RET = RETRIEVE
M/P = MODULE & PALLET
IUS = INTERIM UPPER STAGE

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PAYLOAD TRANSPORTATION TRAFFIC

The payload transportation traffic is summarized by calendar quarter on the facing page. The point of origin for each shipment is the payload development center, or Level IV site. The shipments in the "undefined" row indicate that the Level IV site is presently undefined even though the payload is identified in the payload model.

The sizes listed along the top of the table are payload sizes. "S" (small) payloads are those up to and including 7 feet 2.5 inches in diameter. The "L" (large) payloads are those up to and including 14 ft 4 inches wide and 10.8 feet high. The question mark indicates a lack of payload size definition.

Entries in the "undefined"/question mark squares indicate payloads which are identified in the payload model, but for which both size and development center (Level IV site) definition is lacking.

Initially, payload traffic was defined using three size transportation systems. In addition to the small and large systems described above, a medium system was used to transport payloads with diameters between 7.3 ft and 9.5 ft. The total traffic for each of the three systems through 1982 is summarized below.

SYSTEM SIZE	NUMBER SHIPMENTS	CONTINGENCY LANDINGS AT DFRC (5% of total)	TOTAL SHIPMENTS	PERCENT OF TOTAL
Small	68	3	71	31
Medium	61	3	64	28
Large	64	3	67	29
Unknown	25	1	26	12

TOTAL: 228

At the end of the second study phase it was determined that Spacelab integrated rack/floor assemblies would not be shipped to the Level IV sites and that Spacelab pallet and rack mounted experiments would be removed from the flight hardware at KSC and returned to the Level IV sites separately. These guidelines eliminated most of the requirements for the medium system and reduced the total number of shipments to the levels indicated on the facing chart.

PAYLOAD TRANSPORTATION TRAFFIC

ORIGIN	QUARTER YEAR SIZE		4 79 S L	1 80 S	2 80 ?	3 1980 S L ?	4 1980 S L ?	1 81 S ?	2 81 S ?	3 1981 S L ?	4 1981 S L ?	1 1982 S L ?	2 1982 S L ?	3 1982 S L ?	4 82 S L	NO.	%	
ARC, S. FRANCISCO, CA							1				1	1	1		1	5	4	
GSFC, GREENBELT, MD	1		1					1	3	1 2		1	1	4 4	1 1	21	15	
JPL, PASADENA, CA					2 1	1 1 2	1			1 1	1 4	1	2 2		1 2	23	17	
JSC, HOUSTON, TEX					1		1	3	5 3			1	4 1	1	4	24	17	
LaRC, HAMPTON, VA	2		1					1				1	1 2 2			10	7	
LeRC, CLEVELAND, OH					1 1		1	2	1 1				1			8	6	
MSFC, HUNTSVILLE, AL							2	1	2		1	1	1		1	9	6	
UNDEFINED					4 4 1		2	3	2		2	3	2	2 2 3	2 3 2	2	39	28
TOTAL SHIPMENTS			1 2	1 1	8 6 1	2 3 4	4 4	9 2	10 7 2	3 4 3	5 1 3	13 8 3	6 8 2	9 4		139		

NOTES: 1) Each shipment listed is one way for payload, round trip for T-MMSE.

2) S = Small Payload (Up to 7 ft 2.5 inches wide x 7 ft 6 inches high)
 L = Large Payload (Up to 14 ft 4 inches wide x 10 ft 10 inches high)
 ? = Size Payload Unknown

3) Undefined = Point of Origin (Level IV Site) Undefined.

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CARRIER CAPABILITIES

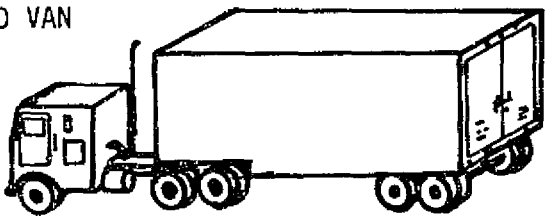
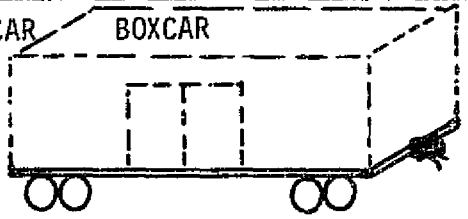
Payload accommodation capabilities were defined for the available carriers including aircraft, road and rail equipment. The facing chart summarizes the carrier dimensions and door sizes.

The Standard size commercial van is 13.5 ft high, 8 ft. wide and 45 ft. long. The van has an air ride suspension system, provides temperature and relative humidity control and can be operated 24 hours a day in normal operations. Flatbed and low bay trailers are also commercially available with air ride capability. Payload environmental control would have to be provided separately in conjunction with the payload cover/container.

Commercial freight cars provide only cooling capability and would require supplemental environmental control.

Several aircraft were assessed as potential payload transporters. The range of door sizes are listed on the chart.

CONCEPT DEFINITION -- CARRIER SUMMARY

	CHARACTERISTICS	DIMENSIONS									
STD VAN 	- SELF-CONTAINED ECS - AIR-RIDE	DOOR - 9'H X 7.6'W (INSIDE) OUTSIDE - 13' 6"H x 8'W x 45'L									
FLATBED/LO-BOY 	AIR-RIDE	FLATBED: OUTSIDE - 3'2"H X 8'W x 45'L LO-BOY: OUTSIDE - 20"H x 8'W x 24'9"L									
FLATCAR BOXCAR 	- FREIGHT CAR SUSPENSION - REFRIGERATION ONLY	FLATCAR - 3' 10"H x 10'W x 40'-89'L REEFER - 15'H x 10'W x 60'L									
AIRCRAFT 	SELF-CONTAINED ECS	DOOR: <table> <thead> <tr> <th></th><th>H</th><th>W</th></tr> </thead> <tbody> <tr> <td>C-5A</td><td>13' 6"</td><td>19'</td></tr> <tr> <td>(UA) 727-QC</td><td>5' 5"</td><td>5'8"</td></tr> </tbody> </table>		H	W	C-5A	13' 6"	19'	(UA) 727-QC	5' 5"	5'8"
	H	W									
C-5A	13' 6"	19'									
(UA) 727-QC	5' 5"	5'8"									

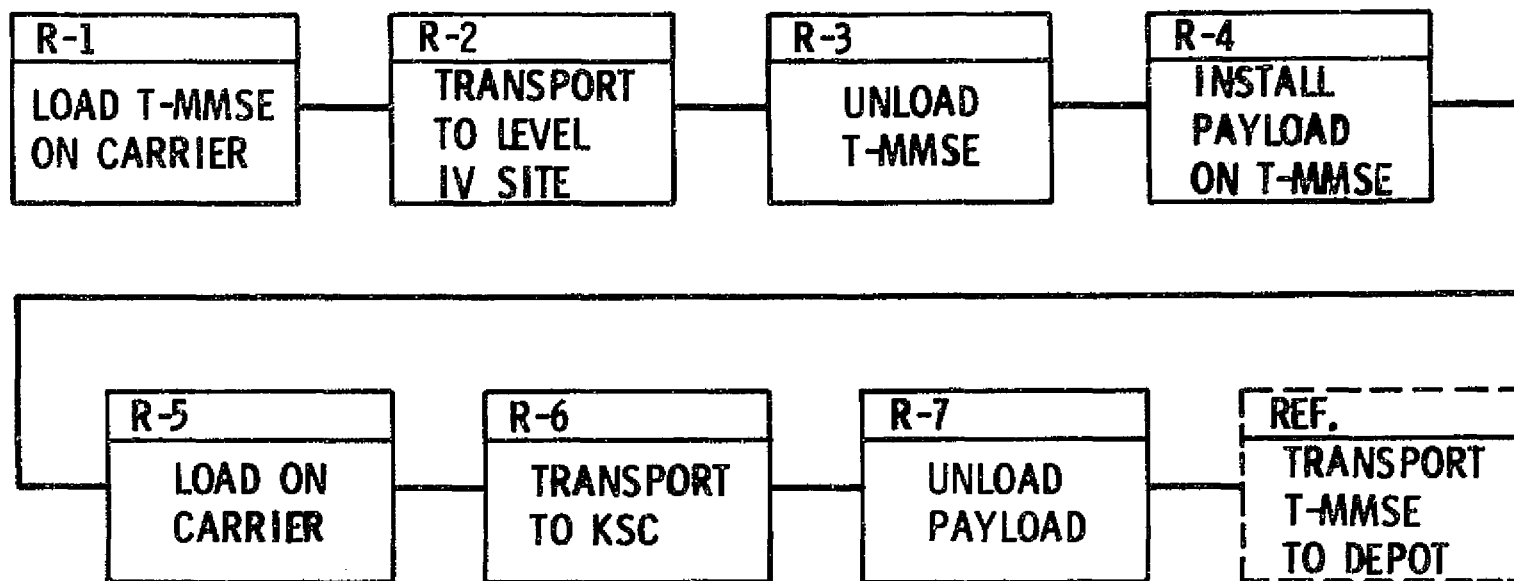
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FUNCTIONAL FLOW - ROAD TRANSPORTATION

Functional flow diagrams were developed as a basis for more detailed timeline analyses to define the specific system requirements.

The baseline functional flow of transporting payloads over the road using enclosed vans or low boys is shown on the facing chart. The empty transportation system is moved to the Level IV site, the payload is loaded into the system and the same carrier is utilized for the total transportation activity.

FUNCTIONAL FLOW - ROAD TRANSPORTATION



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FUNCTIONAL FLOW - AIR TRANSPORTATION

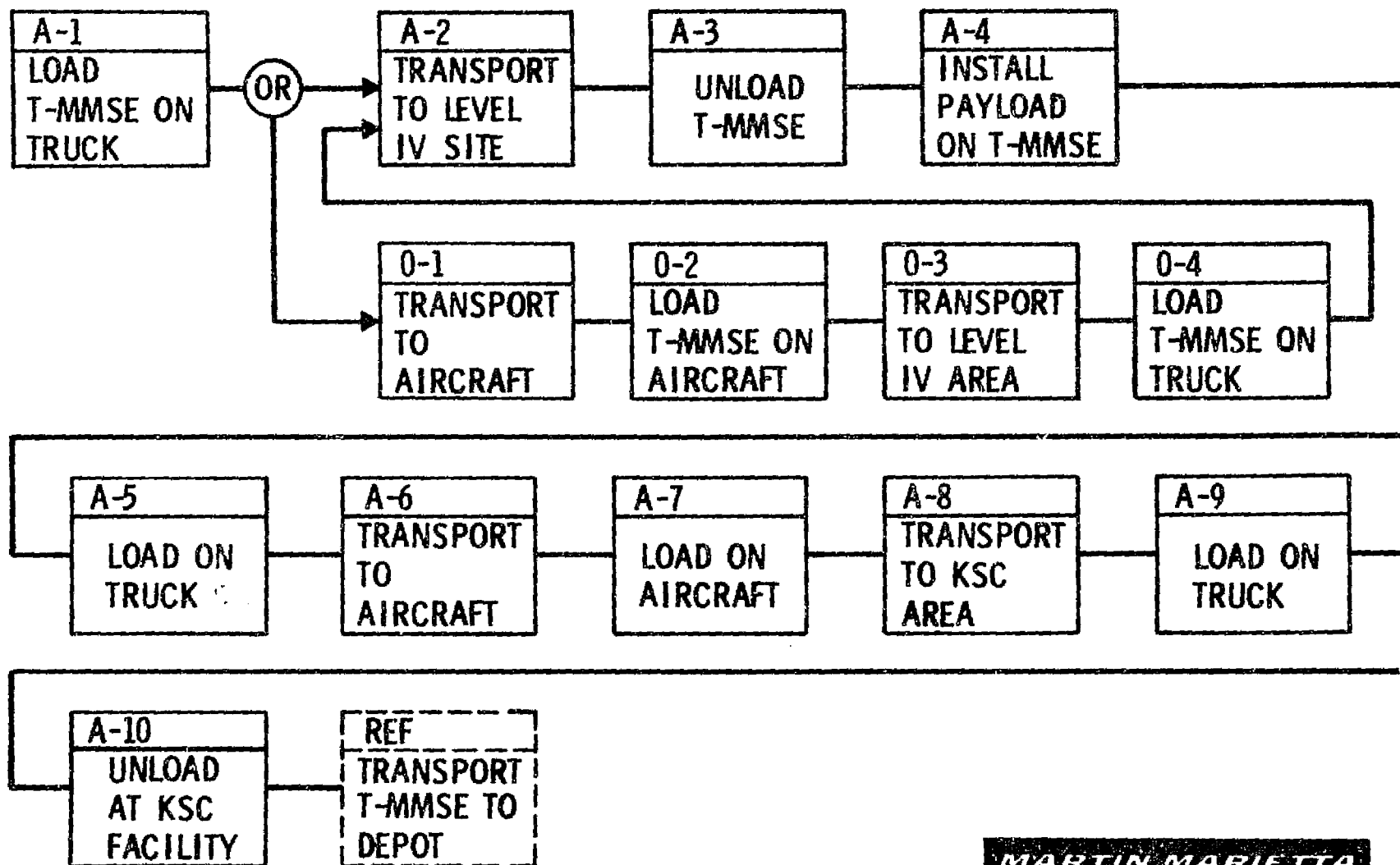
The air mode (and rail mode, for which the facing chart is typical) requires several more payload handling operations than the road mode. Road transportation is required on both ends of the flight transporting the payload. If the optional mode of transporting an empty system to the Level IV site by air (or rail) were used, additional trucking operations would be required. This option is depicted in blocks 0-1 through 0-4 on the facing page.

Top level estimates of the time required for the various modes of travel were generated for use in comparing the concepts. Typical travel times to KSC are listed below.

TYPICAL TRANSPORT TIMES (ELAPSED)

MODE \ ORIGIN	GSFC	MSFC	JPL
Rail	3 Days	4-5 Days	14 Days
Air	1-2 Days	1 Day	2-3 Days
Road	1-2 Days	1 Day	3-4 Days

FUNCTIONAL FLOW - AIR TRANSPORTATION



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CANDIDATE CONCEPTS

The approach used in developing candidate transportation concepts is shown on the facing chart. The major options that were assessed in developing the concepts are as follows:

MODE

- Air
- Road
- Rail
- Combinations

CARRIER

- Aircraft Type
- Van, Flatbed, Low-Boy
- Boxcar, Flatcar

CONTAINER

- Soft
- Hard

TRANSPORTATION MMSE

- Payload Adapters
- Sling Sets
- Tie-Down Kits

ANCILLARY EQUIPMENT

- Cranes
- Forklifts
- Loaders

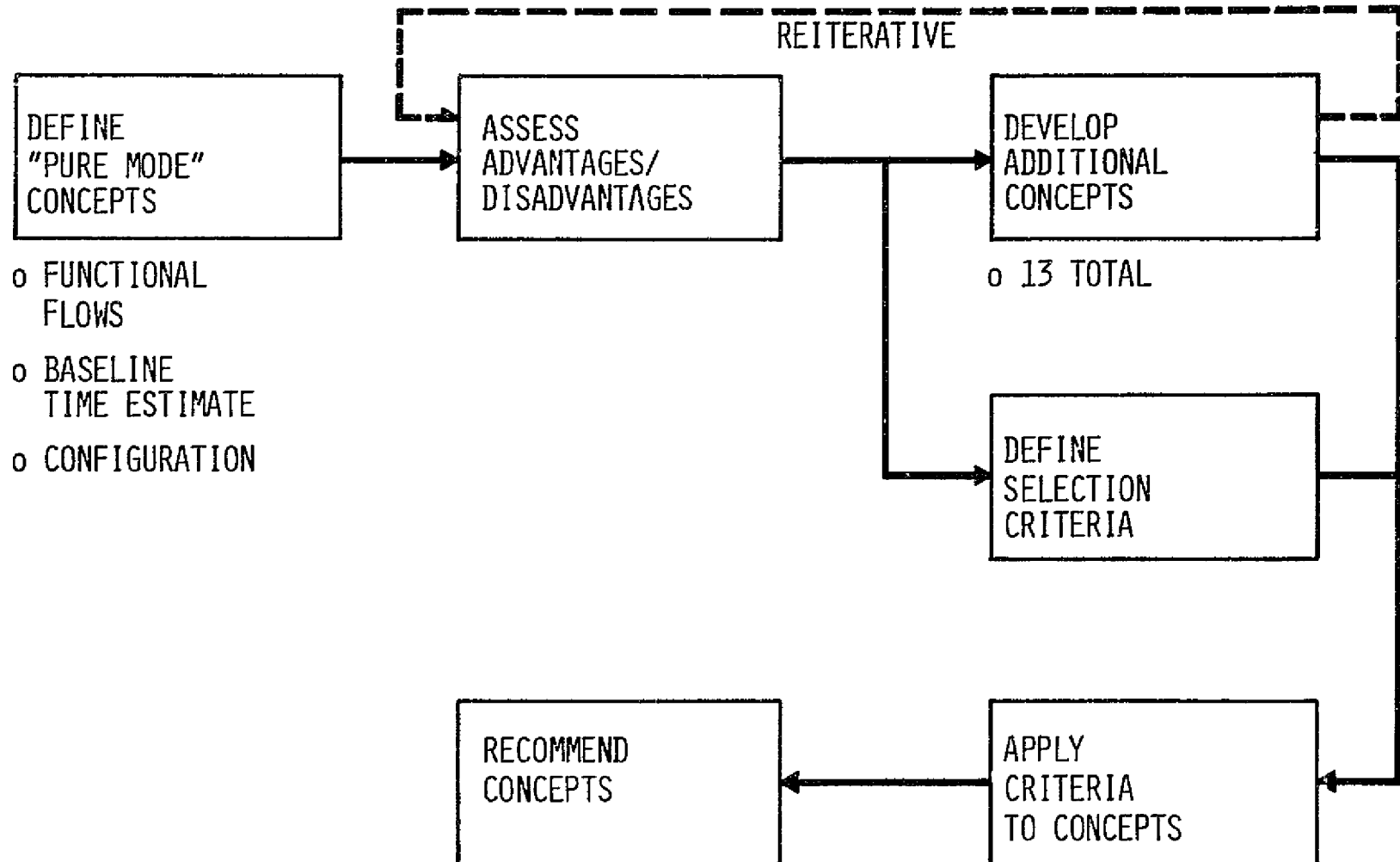
SYSTEM SIZING

- Accommodate Full Range of Payloads in One Size System.
- Group Payloads and Systems into Various Sizes.

Considering various combinations of these options, thirteen different concepts were derived. Beginning with a separate concept for each "pure" mode (all air, all rail, all road), the advantages and disadvantages of each was defined and additional concepts developed.

To select the most promising concepts for further evaluation a set of criteria was developed and applied to each concept.

CANDIDATE CONCEPTS - APPROACH



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CANDIDATE CONCEPT - RAIL MODE

The facing chart shows an example of the type of data that was defined for each concept. The payloads were separated into classes (automated and Spacelab) and then grouped into sizes. The transport mode and carriers capable of accommodating the various sizes were identified as was the container type and size, the transportation MMSE required and the ancillary equipment required.

Each of the thirteen concepts was documented to this level for each payload class and size group. A summary of each concept is shown on the following chart.

CANDIDATE CONCEPT - RAIL MODE (TYPICAL)

PAYLOAD CLASS SIZE	MODE	CARRIER	CONTAINER	TRANSPORT MMSE	ANCILLARY EQUIPMENT
AUTO < 9' DIA	RAIL	FLATCAR	HARD 9'8"Hx9'8"Wx18-20'L	-STD ECS -TRANSPORT PALLET -TIE-DOWN KIT -INSTRUMENTATION KIT -SHOCK ISOLATION SYSTEM	-RAMP/CRANE -SLINGS -COME ALONG
> 9' DIA	RAIL	FLATCAR	HARD 10'2"Hx12'10.5"W x 14'L	SAME AS ABOVE	SAME AS ABOVE
SL SINGLE RACK	RAIL	FLATCAR	HARD 4'6"Hx3'Wx10'L	-STD ECS -TIE DOWN KIT -INSTRUMENTATION KIT	-RAMP/CRANE -SLINGS -COME ALONG

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CANDIDATE CONCEPT SUMMARY

The thirteen candidate concepts are summarized on the facing chart. The concepts are listed in the left column with the applicable container and carrier noted for the three payload size groupings. Note that the primary differences between concepts concerns mode of transport, type, size and number of containers, and type of carrier. Most of the concepts provide only one combination of container and carrier. For example, Concept 4 utilizes a small size, hard container on a flatbed for small payloads, a medium size hard container on a flatbed for medium payloads, and a large size hard container on a flatbed for large payloads. In this concept the same carrier is used for all payload sizes and three different size containers are required.

Several of the concepts provide options for the small payloads, such as Concept 8 in which small payloads may be accommodated in either a soft container in a van or in a hard container on a flatbed. In some concepts fewer than three size containers are provided - for example, Concept 6 accommodates all payloads in the large container.

Combinations of mode, carrier and container type were assessed for all payload sizes. The accommodation of small payloads were assessed for both road and air transport in various aircraft and both van and flatbeds and in both soft and hard containers. Medium and large payload accommodation was assessed for both modes of travel but only in hard containers. A special study task assessed the feasibility of using soft containers for medium and large payloads, particularly in cases where a payload was excluded from being transported on specific carriers due to the envelope of the hard container.

CANDIDATE CONCEPT SUMMARY

CONCEPT	P/L SIZE	SMALL		MEDIUM		LARGE	
		CONTAINER	CARRIER	CONTAINER	CARRIER	CONTAINER	CARRIER
1. PURE RAIL		HARD MEDIUM	FLATCAR	HARD MEDIUM	FLATCAR	HARD LARGE	FLATCAR
2. PURE AIR		SOFT SMALL	ANY	HARD MEDIUM	747, 130, 141, C-5A	HARD LARGE	747, 130, 141, C-5A
3. PURE ROAD		SOFT SMALL	VAN	HARD MEDIUM	FLATBED	HARD LARGE	FLATBED
4. ALL FLATBED (ROAD)		HARD SMALL	FLATBED	HARD MEDIUM	FLATBED	HARD LARGE	FLATBED
5. ALL FLATBED (ROAD)		HARD MEDIUM	FLATBED	HARD MEDIUM	FLATBED	HARD LARGE	FLATBED
6. ALL FLATBED (ROAD)		HARD LARGE	FLATBED	HARD LARGE	FLATBED	HARD LARGE	BLATBED
7. ALL BLATBED (ROAD)		HARD SMALL	FLATBED	HARD LARGE	FLATBED	HARD LARGE	FLATBED
8. VAN & FLATBED (ROAD)		SOFT/SM HARD/SM	VAN FLATBED	HARD MEDIUM	FLATBED	HARD LARGE	FLATBED
9. VAN & FLATBED (ROAD)		SOFT/SM HARD/SM	VAN FLATBED	HARD LARGE	FLATBED	HARD LARGE	FLATBED
10. VAN & FLATBED (ROAD)		SOFT SMALL	VAN	HARD LARGE	FLATBED	HARD LARGE	FLATBED
11. AIR & ROAD		SOFT SMALL	AIR	HARD MEDIUM	AIR	HARD LARGE	FLATBED
12. AIR & ROAD		SOFT SMALL	VAN	HARD MEDIUM	AIR	HARD LARGE	FLATBED
13. AIR & ROAD		SOFT SMALL	AIR	HARD MEDIUM	FLATBED	HARD LARGE	FLATBED

CONCEPT SELECTION CRITERIA

Selection criteria were derived, based on the apparent advantages and disadvantages of each of the concepts, to ensure a standard of evaluation for each concept. Each criterion was not intended to assess each total concept, but, rather ensured that whether a part of each concept, such as hard vs soft containers was under consideration or a broader aspect such as transportation mode was being evaluated, each item was assessed in terms of identical considerations.

The selection criteria and the primary considerations of each are listed below.

Crew Availability - How available is the crew of the prime carrier for equipment operation and maintenance.

Carrier Availability - Is the prime carrier readily available.

Number of Payload Handling Operations - How many times must the payload be handled during the transportation cycle.

Weather Limitations - What delay could be encountered due to inclement weather.

Portal-to-Portal Time - Elapsed time from the beginning of the payload transport function to unloading at the desired facility.

Equipment Required - Amount of carrier, T-MMSE, and ancillary equipment required during the total transportation activity.

Induced Dynamic Environment - Levels of induced environment (shock, vibration, temperature, relative humidity, etc.), generated by the system concepts which could be transmitted to the payload.

Accessibility for Intransit Maintenance - Is the T-MMSE accessible for maintenance and repair when in transit.

Security - How vulnerable is payload to damage by accident or vandalism during transport and what is the ease of monitoring payload status.

Feasibility of Carrier Dedication - Can the carrier reasonably be dedicated to transporting a specific payload to the exclusion of other cargo on the same trip.

CONCEPT SELECTION CRITERIA

1. CREW AVAILABILITY
2. CARRIER AVAILABILITY
3. NUMBER OF PAYLOAD HANDLING OPERATIONS
4. WEATHER LIMITATIONS
5. PORTAL-TO-PORTAL TIME
6. EQUIPMENT REQUIRED
7. INDUCED DYNAMIC ENVIRONMENT
8. ACCESSIBILITY FOR IN-TRANSIT MAINTENANCE
 - POWER
 - ECS
 - INSTRUMENTATION
9. SECURITY
 - ACCIDENT VULNERABILITY
 - VANDALISM VULNERABILITY
 - STATUS MONITORING
10. FEASIBILITY OF CARRIER DEDICATION

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TRANSPORTATION SYSTEM CONCEPT RANKING

Each concept was ranked against the criteria to evaluate the acceptability of the concept. The concepts were scored on the basis of 1 for an "Excellent" rank against any given criterion and 5 for a "Poor" ranking. The results of the concept ranking are shown on the facing page.

The "Transport Concept" numbers along the top of the table correspond to those on the Candidate Concept Summary Chart. For example, Concept 6 is a road concept with all payloads transported on a flatbed (lowboy) using a single size hard container.

The concept ranking was essentially a subjective process based on engineering judgment and guided by a consistent application of the criteria. Wide ranking differences resulted among the concepts when ranked against some of the criteria. For example, in ranking each concept in terms of the elapsed time required for payload transportation (Portal to Portal time), poor scores (5) are noted for concepts number 1 and number 6. Concept 1 is an all rail transportation system. Rail travel is slowest of the concepts assessed due to low rates of travel while in transit and also due to the requirement for rather extensive switching from train to train as the rail car is moved across the country.

Concept 6, described previously, is ranked Poor since to accommodate all payloads in a single, hard container on a flatbed, every payload shipment would be a wide load on which are imposed reduced speed limits and limits as to hours of the day and days of the week that the load can be moved over interstate highways.

The concepts which consume the least elapsed time for payload shipments are numbers 2 and 11. Concept 2 is an all air system and concept 11 uses aircraft to transport all payloads except the large ones which are shipped on flatbeds. Although air transportation modes require road travel on both ends of the shipment, which adds time to the overall process, air is still the least time consuming mode.

The final ranking scores did not result in an indisputable choice of the best transportation concept, but did provide some guidelines regarding desirable concept features. The final scores indicate that rail transportation has serious limitations and was therefore dropped from further study consideration.

Air and road modes both have desirable features and were carried into the detailed analysis phase of the study. Although the final scores for specific air and road concepts were not discriminatory, Concepts 8 and 11 (modified) were recommended for further consideration. These two concepts, summarized on the facing page, were selected since they ensured that each major system element (carrier, container, equipment) would be defined and costed, thereby ensuring detailed definition of the most cost-effective and efficient system.

TRANSPORTATION SYSTEM CONCEPT RANKING

CRITERIA \ TRANSPORT CONCEPT	ROAD AIR RAIL			ROAD							AIR/ROAD		
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. CREW AVAILABILITY	4	3	1	1	1	1	1	1	1	1	3	2	2
2. CARRIER AVAILABILITY	1	3	1	1	1	1	1	1	1	1	2	2	1
3. NUMBER HANDLING OPS	4	4	1	1	1	1	1	1	1	1	3	2	2
4. WEATHER LIMITS	1	2	4	4	4	4	4	4	4	4	2	3	3
5. TIME - PORTAL-to-PORTAL	5	1	3	3	4	5	4	3	3	4	1	2	2
6. EQUIPMT REQ'D (SUPT & ANC)	3	3	1	1	1	1	1	1	1	1	2	2	2
7. DYNAMIC ENVIRONMENT	4	3	1	1	1	1	1	1	1	1	3	2	2
8. ECS ACCESS	3	2	1	1	1	1	1	1	1	1	2	1	1
9. SECURITY	2	1	3	3	3	3	3	3	3	3	1	2	2
10. DEDICATED CARRIER	3	2	1	1	1	1	1	1	1	1	2	1	1
FINAL SCORE:	30	24	17	17	18	19	18	17	17	18	21	19	18

LEGEND: 1 - EXCELLENT
 2 - GOOD
 3 - AVERAGE
 4 - FAIR
 5 - POOR

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CONCEPTS SELECTED FOR DETAILED DEFINITION

A total of thirteen (13) transportation system concepts were developed during the first study phase. The concepts included three "pure" concepts (air, road, rail) in which all payloads were transported using a single mode. The other ten (10) concepts were combinations of transport mode and/or container concepts. The review of each concept resulted in the following conclusions: 1) Eliminate the "all-air" and rail concepts, based on top-level cost and elapsed time considerations; 2) Carry two concepts forward into the Phase-II activities which would ensure that the primary elements of the air and road systems would be evaluated and costed to ensure development of the most cost-effective option.

The following notes apply to the facing chart.

- (1) One of the following aircraft depending on payload dimensions: 727-100, 727-QC, 747-P, DC-10-30, 727, Gulfstream, DC-8F cargo.
- (2) One of the following aircraft depending on payload dimensions: C-5A, 747F, C-130, C-141

* Added to basic Concept #11 to treat case of large payloads by air.

CONCEPTS SELECTED FOR DETAILED DEFINITION

CHARACTERISTIC CONCEPT	MODE	CARRIER	CONTAINER
#8			
SMALL PAYLOADS a)	ROAD	VAN	SOFT
b)	ROAD	FLATBED	HARD
MEDIUM PAYLOADS	ROAD	FLATBED	HARD
LARGE PAYLOADS	ROAD	FLATBED	HARD
#11			
SMALL PAYLOADS	AIR	AIRCRAFT ⁽¹⁾	SOFT
MEDIUM PAYLOADS	AIR	AIRCRAFT ⁽²⁾	HARD
LARGE PAYLOADS a)	ROAD	FLATBED	HARD
* b)	AIR	AIRCRAFT ⁽²⁾	HARD

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CONCEPT DEFINITION - APPROACH

The concepts defined on the previous chart were evaluated in detail during study Phase II. The general flow of activities required to select a recommended baseline transportation system is shown on the facing chart. Engineering systems design, logistics and cost and schedule data were generated for each concept. Trade studies were conducted to support choices at the element level (container, adapter, support equipment usage).

Selection criteria based on the advantages and disadvantages of each system were derived to enable selection of the most cost-effective system.

CONCEPT DEFINITION - APPROACH

CONCEPTS FROM STUDY
PHASE I:

DEVELOP ENGINEERING DATA

- o PAYLOAD ENVELOPES
- o EQUIPMENT LAYOUTS
- o WEIGHT ESTIMATES
- o CONFIGURATIONS

DEVELOP SYSTEMS DATA

- o ECS REQUIREMENTS
- o SUPPORT REQUIREMENTS
- o FACILITY REQUIREMENTS

DEVELOP LOGISTICS DATA

- o TIMELINES
- o TRAFFIC ANALYSIS
- o MAINTENANCE/SPARES

DEVELOP PROGRAMMATICS DATA

- o COST
- o SCHEDULE

PROGRAM RECOMMENDATION

- o SELECTION CRITERIA
- o RATIONALE

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SYSTEM HARDWARE CONCEPTS

In order to evaluate the concepts properly, various design concepts, configurations and manufacturing techniques were defined for the hardware items listed on the facing chart.

Containers are required to transport the various configurations of payloads.

Payload Adapters are required to interface with the payload, and secure it to the container.

Sling Sets are required to lift the containers and associated equipment during the transportation cycle.

Environmental Control Systems provide control of the payload environment in the medium and large systems. During transit the ECS is required at all times when not in an environmentally controlled facility.

The Auxiliary Power Unit is required as part of the medium and large systems to provide power for the payload, service power, Transportation Environmental Monitor System and the Environmental Control System.

The Transportation Environment Monitor System monitors and records environmental data during payload shipment. Engineering data will be monitored and recorded for shock, acceleration, temperature, relative humidity, and payload power.

SYSTEM HARDWARE CONCEPTS

		TRANSPORTATION MMSE															ANCILLARY		
SYSTEM SIZE	HARDWARE	ADAPTERS																	
		SOFT COVER	HARD COVER	PLATFORM	AUTO END	AUTO CENTER	PALLET (H)	PALLET (V)*	RACK*	APU/ECS	TEMS	SLING KIT	TIE-DOWN KIT	DUST BAG	HYDROSET	TRACTOR	VAN	LOW-BOY	ESCORT VEH
SMALL		X		X	X	X					X	X	X	X		X	X		X
MED			X	X	X				X	X	X	X	X	X	X		X	X	
LARGE			X	X	X		X	X	X	X	X	X	X	X	X		X	X	

* SPACELAB GSE

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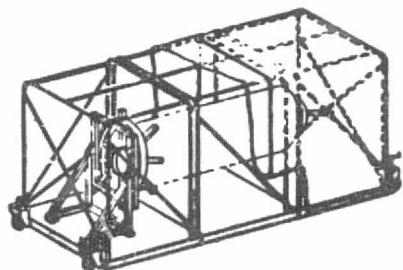
CONTAINER CONCEPTS

Several container concepts (consisting of a transport platform and cover) were developed and assessed during this phase of the study. Some of the concepts are depicted on the facing chart. The soft cover with a segmented platform, in the upper left, was developed for use with a standard size van or in aircraft where clearances were critical and the larger hard covered containers could not be accommodated.

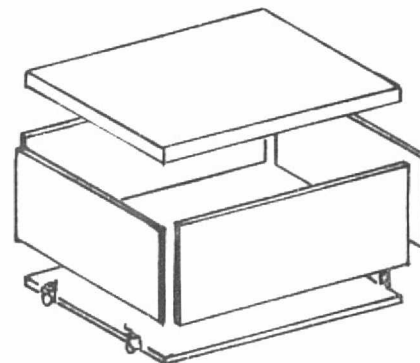
The other three concepts shown are hard containers. All of the concepts were developed to meet the following listed requirements. The containers must:

- Accommodate a wide range of payload sizes, weights and configurations,
- Environmentally protect the payloads during transport,
- Be compatible with both road and air transport,
- Provide payload service interfaces,
- Provide access for loading/unloading payloads,
- Be compatible with facilities at level-IV sites and launch site.

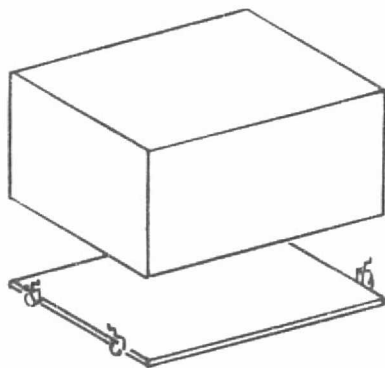
CONTAINER CONCEPTS



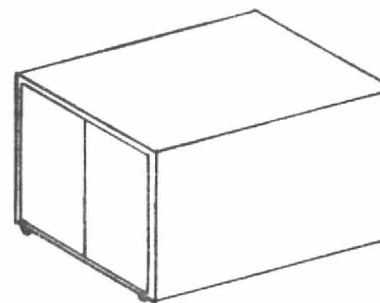
SEGMENTED SOFT COVER



SEGMENTED ASSEMBLY



SEPARATE COVER/PLATFORM



INTEGRAL COVER/PLATFORM

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PAYLOAD ADAPTER CONCEPTS - AUTO AND AUTO/IUS

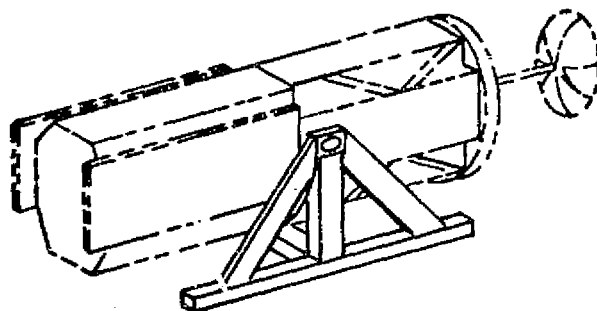
Payload adapters were developed to accommodate various Payload configurations to the transport platform. The adapter design must provide shock isolation from the carrier and be able to compensate for the variation of payload weights and center of gravity changes. The various payload flight interfaces were identified and the adapters were designed to utilize the same interfaces.

The facing chart depicts concepts for automated end and center mounted payloads, and automated/IUS end mounted payloads.

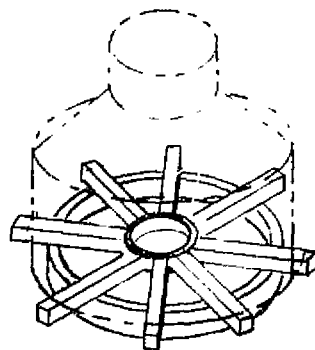
The transport platform interface must be compatible with all adapters using various tie down techniques.

Another adapter, not shown, is the Space Lab Rack Adapter which is GFP as part of the Spacelab Program.

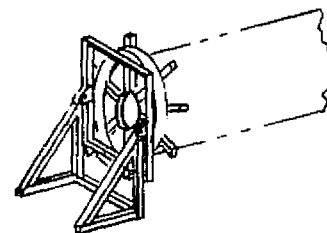
PAYLOAD ADAPTER CONCEPTS - AUTO/IUS & AUTO



(FSS) CENTER-MOUNTED



END-MOUNTED VERTICAL



END-MOUNTED HORIZONTAL

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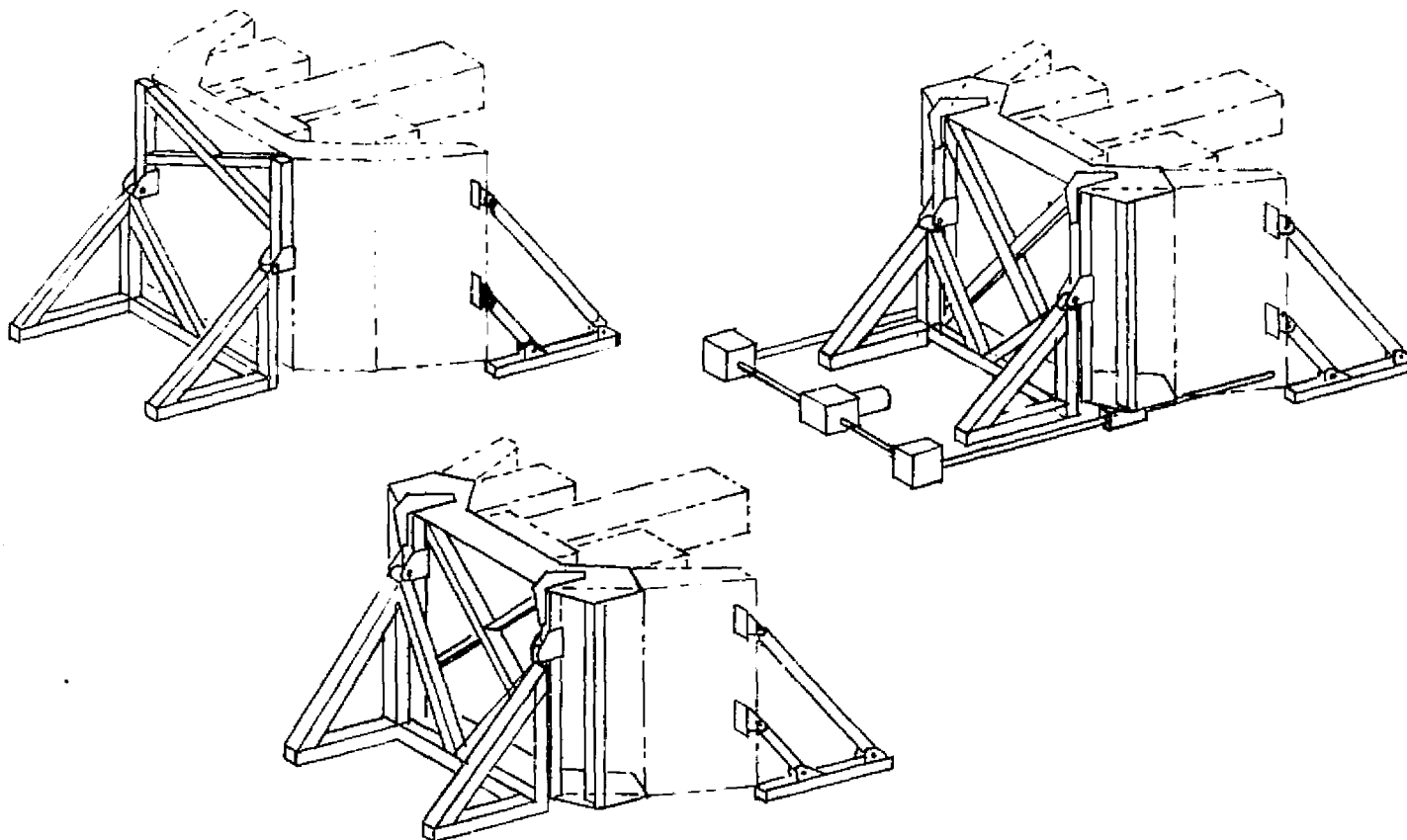
PAYLOAD ADAPTER CONCEPTS - SPACELAB PALLET

The facing page shows three different concepts for an adapter to transport the pallet in the horizontal attitude. This pallet has the capability of rotating the pallet horizontally as well as adapting the pallet to the transport platform.

An analysis was performed to determine proper rotation and handling for design efficiency. Concepts which use an overhead crane for rotation and also self-powered units were defined and assessed.

Another Spacelab program item can be used to transport pallets in the vertical position if the overall height of the pallets plus experiments are not greater than 10.8 feet.

PAYLOAD ADAPTER CONCEPTS - SPACELAB PALLET



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SLING SET

Lifting Sling Sets are required for handling the containers at the Level IV Site and the Launch Site. A trade was performed to determine the feasibility of utilizing one sling assembly to handle all of the containers and rotate the Spacelab pallet to the horizontal position. The assembly must also have the capability to be transported with the containers. The facing chart shows a versatile design to accomplish the required operations with a single assembly.

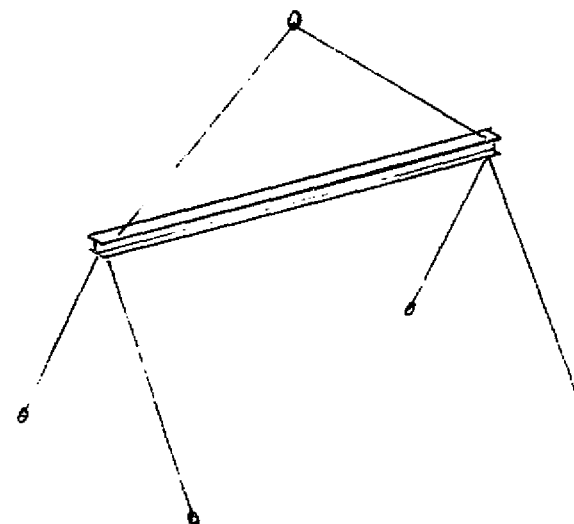
LIFTING SLINGS

WEIGHT - CONTAINER 1725#

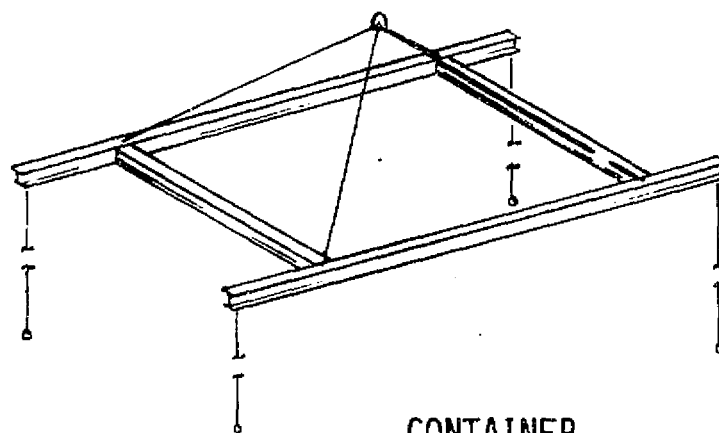
- PALLET 450#

CAPACITY - CONTAINER 20,000#

- PALLET 14,000#



PALLET



CONTAINER

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APU/ECS CHARACTERISTICS

The transportation system is required to control the environment surrounding payloads during transportation and to provide power to the payload on an as required basis. When the van is utilized for transporting the payloads, the environmental control capability and electrical power is provided by the van. For all other carriers, however, the capability must be provided.

The APU must provide power during transit for the environmental control unit, transporter environmental monitor system and for the payload.

The Environmental Control unit must provide and maintain environmental control of the payload during transit by controlling temperature at $70 \pm 5^{\circ}\text{F}$, relative humidity between 30% and 50% and payload cleanliness to the Level IV Site requirements.

Trade studies of various concepts resulted in the definition of a combined unit as the most cost effective and efficiently packaged option. The facing page provides characteristics of four units which were defined and costed.

APU/ECS CHARACTERISTICS

APU/ECS CAPABILITIES	PAYLOAD SIZE			
	<u>SMALL</u>	<u>MEDIUM</u>	<u>LARGE</u>	<u>ALL IN A/C</u>
COOLING CAPACITY	12,000 BTU	18,000 BTU	24,000 BTU	12,000 BTU
HEATING CAPACITY	2-1/2 KW	3-1/2 KW	4-1/2 KW	2 KW
POWER	208 VAC 3-PHASE 50/60 HZ	208 VAC 3-PHASE 50/60 HZ	208 VAC 3-PHASE 50/60 HZ	115 VAC 3-PHASE 400 HZ
CONDITIONED AIR SUPPLY (CFM)	400 CFM	600 CFM	800 CFM	400 CFM
MAX OPERATING AMBIENT	120° F	120° F	120° F	100° F
MIN OPERATING AMBIENT	-40° F	-40° F	-40° F	-0° F
WEIGHT	1200#	1500#	1800#	400#
APU RATING	3 KW	4 KW	5 KW	C130/C141/C5A
APU/ECS DIMENSIONS	36"H x 36"W x 90"L	48"H x 48"W x 90"L	48"H x 48"W x 90"L	36"H x 36"W x 45"L

NOTE:

APU PROVIDES 208 VAC 3-PHASE 50/60 HZ AND 28 +/- 4 VDC, INCLUDING 28 VDC BATTERY TO PAYLOAD AND TEMS FOR 4 HOURS.

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TRANSPORTER ENVIRONMENT MONITOR SYSTEM CHARACTERISTICS

The Transporter Environment Monitor System (TEMS) provides instrumentation for continuous in-transit monitoring and recording of the payload environment including temperature, relative humidity, power, shock and acceleration. The system also contains an alarm system to alert the system operators of out-of-tolerance indications of shock, temperature, relative humidity and payload power. When used during ground transportation, the alarm is transmitted to the cab of the prime mover and to the escort vehicle.

Indicators for temperature and relative humidity are also provided for real time indications without requiring tape readouts.

TRANSPORTER ENVIRONMENTAL MONITOR SYSTEM CHARACTERISTICS

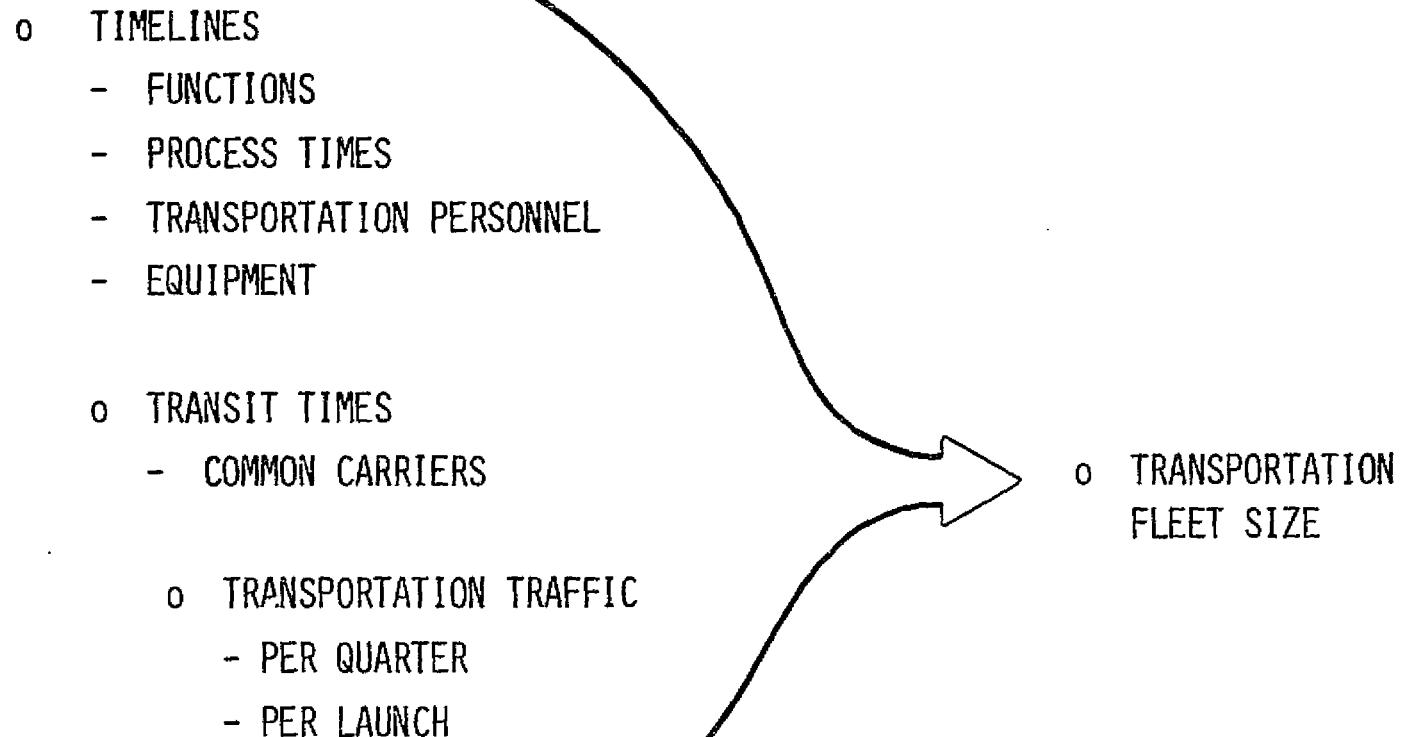
TEMS HARDWARE	QUANTITY RECORD CHANNELS	SIZE	CHARACTERISTICS
ACCELEROMETERS	9	1" x 1" x 1"	$\pm 2\%$ /10 MILLIVOLTS/G @ 1-1000 Hz
TEMPERATURE SENSORS	1	3 1/4" x 4 1/2"	$\pm 2^{\circ}$ ACCURACY
RELATIVE HUMIDITY SENSOR	1	3 1/4" x 4 1/2"	13 - 99% RANGE
POWER LEVEL MONITOR	1	TBD	28 $\pm$ 4 VDC
TIME DATA GENERATOR	1	TBD	$\pm 1 \times 10^{-7}$ DAYS/DAY ERROR
RECORDER, TAPE 1/2"	14	3' x 3' x 8'	14 CHANNEL 110 VAC/ 28 VDC - 1 7/8 IPS 6.4 HRS/ 3600 FT TAPE
THRESHOLD DETECTOR ALARM	4	TBD	TEMPERATURE 70 $\pm$ 5 $^{\circ}$ F RELATIVE HUMIDITY <30% - >50% POWER 28 $\pm$ 4 VDC SHOCK >TBD Gs

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SYSTEMS/LOGISTICS ANALYSIS - APPROACH

Three primary tasks were worked to determine the quantities of equipment required to accommodate the payload-related shipments to and from the launch site through 1982. Functional flows and timelines were developed to define the functions, processing times, transportation personnel and equipment required for each payload shipment, based on payload size, transit requirements and mode of travel. The timelines provided estimates of the time required for all functions with the exception of transportation times. The transportation times (Portal-to-portal) were estimated by common carriers and were added to the timeline estimates to determine the involvement of transportation MMSE for each transport function from each level-IV site. The total number of transport functions were derived for each calendar quarter and for each STS launch to define total T-MMSE usage and transportation fleet size.

SYSTEMS/LOGISTICS ANALYSIS - APPROACH



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SYSTEMS/LOGISTICS GUIDELINES

The guidelines listed in the facing chart form the basis for the systems/logistics analysis and fleet size determination. The first four guidelines were supplied by NASA either in the statement of work or during the study and the final three were developed by the study team during the study tasks. The first two study team guidelines related to depot location and movement of empty MMSE to the user are based on cost increases involved with remote depot location and other modes of transportation (air).

The NASA guidelines which have the greatest impact on transportation system physical size and fleet size are those related to the shipment of multiple elements in support of a single Shuttle launch and the lack of a requirement to accommodate integrated Spacelab rack/floor assemblies.

GUIDELINES FOR FLEET SIZING

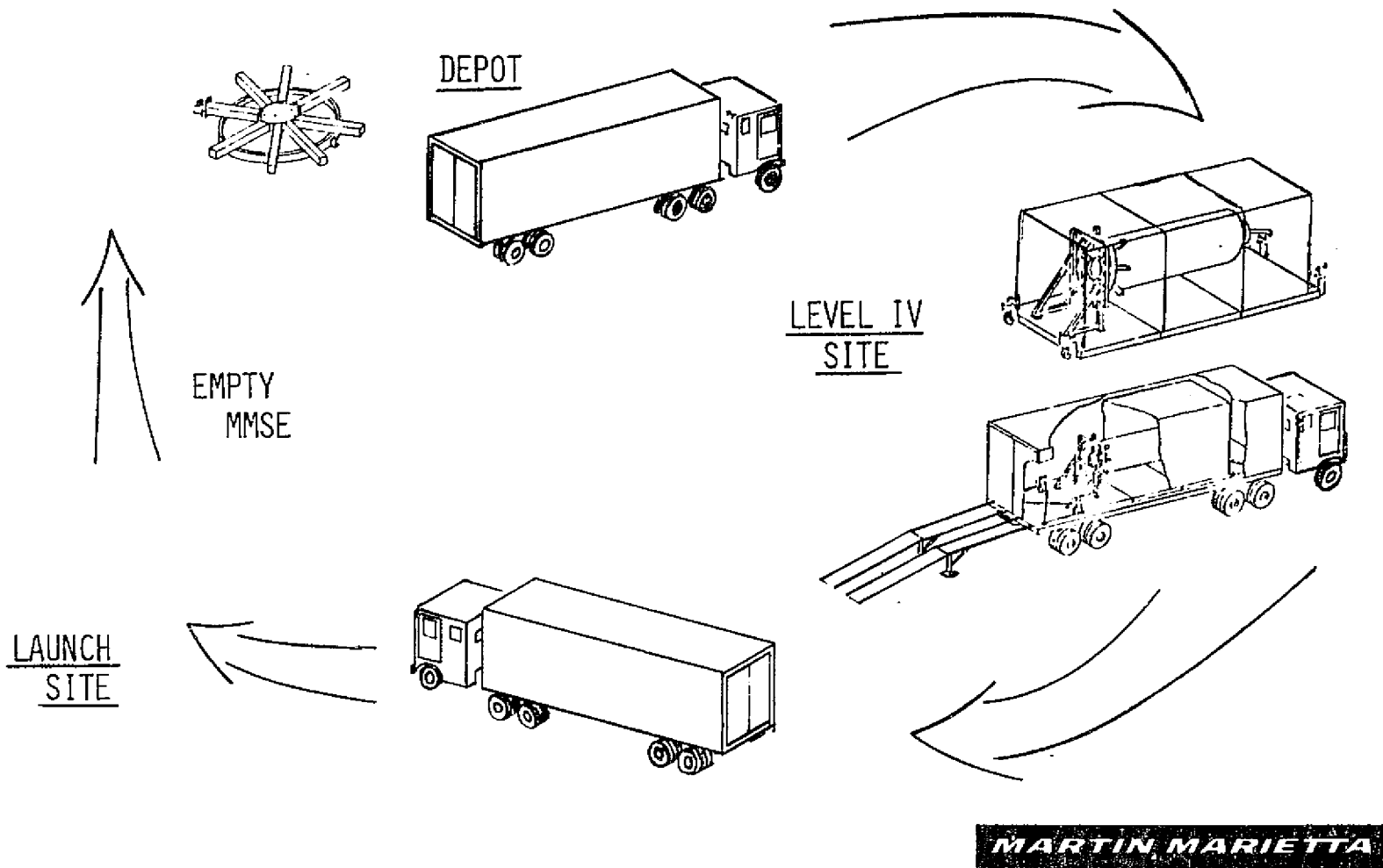
- o CONTINGENCY SHUTTLE LANDINGS AT DFRC ADD 5% USAGE OF TRANSPORTATION SYSTEM
- o ELEMENTS OF SAME SHUTTLE CARGO MUST BE AVAILABLE AT KSC AT THE SAME TIME
- o SPACELAB RACK AND PALLET-MOUNTED EXPERIMENTS WILL BE DEINTEGRATED POST LANDING AT THE LAUNCH SITE AND RETURNED TO THE LEVEL-IV SITES IN THEIR OWN SHIPPING CONTAINERS
- o SPACELAB RACK/FLOOR ASSEMBLIES WILL NOT BE SHIPPED TO THE LEVEL-IV SITES
- o MOVEMENT OF NON FLIGHT-TYPE HARDWARE, PALLET TRAINS, EMPTY PALLETS/RACKS AND EXPERIMENT HARDWARE TO THE LEVEL-IV SITES NOT CONSIDERED
- o KSC IS DEPOT FOR TRANSPORTATION MMSE
- o GROUND TRANSPORTATION OF T-MMSE TO USER IS BASELINE
- o ALL ITEMS OF T-MMSE ARE DEDICATED TO REQUIRED PAYLOAD OPERATIONS FROM DEPOT TO DEPOT (SINGLE-CYCLE)

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PAYLOAD TRANSPORTATION SCENARIO - ROAD

The facing page depicts the flow of the small system through a road cycle from the Level IV site to the launch site and back to the depot. The empty T-MMSE is transported to the user (baseline via road) where the payload is installed, transported to KSC and the empty system returned to the depot. The same carrier is used throughout the cycle from payload installation through delivery to the required facility at the launch site.

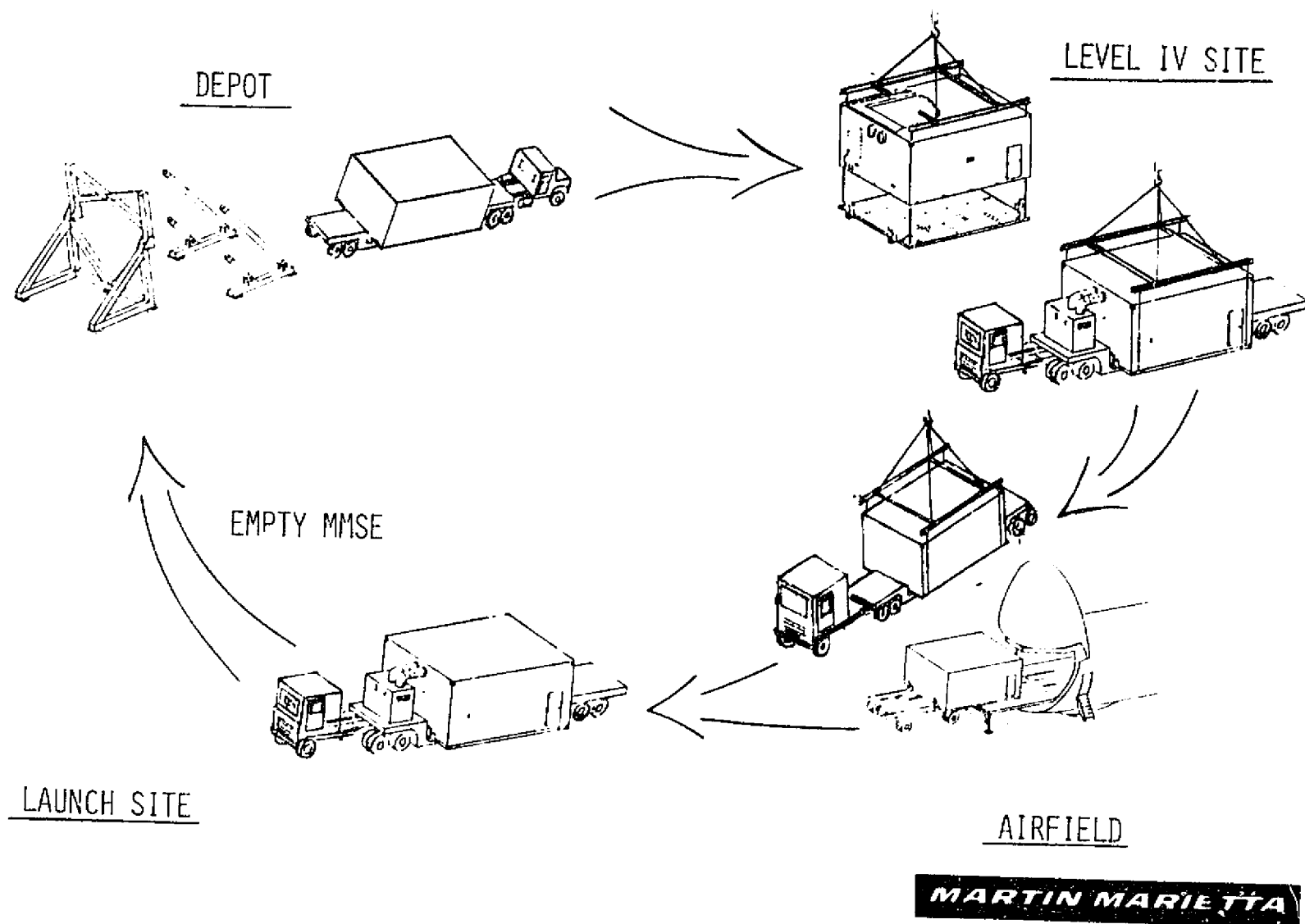
PAYLOAD TRANSPORTATION SCENARIO - ROAD



PAYLOAD TRANSPORTATION SCENARIO - AIR

The facing chart depicts the flow of a payload and the transportation system through a complete cycle using air transportation. As in the road scenario, the empty T-MMSE is shipped to the Level IV site via road. In this case the large container is shipped on a lowboy trailer. At the Level IV site the payload is installed in the system and transported via lowboy to the airfield where it is loaded on the aircraft. After landing at (near) KSC, the container with payload is again loaded on a lowboy for movement to the required facility where the payload is unloaded and the T-MMSE returned to the depot area.

PAYLOAD TRANSPORTATION SCENARIO - AIR



TRANSPORTATION TIME SUMMARY

The matrix on the facing chart summarizes the transportation times from the Level IV sites to KSC (or vice versa) for each size payload using either road or air mode of travel. The times were derived by combining the processing times (load, instrument, unload, etc.) from the time-lines developed during the study and the transit times provided by commercial trucking firms and military air transport organizations.

The top entry is the number of hours required for the total transport operation including shipment of the T-MMSE to the user, loading, transporting, and unloading the payload at KSC and returning the T-MMSE to the depot. The numbers in parenthesis are the elapsed time, in days, to complete the operation. The small road systems operate 24 hours a day and the medium and large can be operated only 10 hours a day. All of the air transportation functions are assumed to operate 24 hours a day.

TRANSPORTATION TIME SUMMARY

ORIGIN \ SIZE/MODE	SMALL		MEDIUM		LARGE	
	ROAD	AIR	ROAD	AIR	ROAD	AIR
ARC	126 (5.25)	86.3 (3.6)	167 (16.7)	96.5 (4.0)	188 (18.8)	96.5 (4.0)
GSFC	75 (3.1)	82.6 (3.4)	96 (9.6)	94.7 (3.9)	103 (10.3)	94.7 (3.9)
JPL	118 (4.9)	88.9 (3.7)	155 (15.5)	99.6 (4.2)	173 (17.3)	99.6 (4.2)
JSC	78 (3.25)	83.5 (3.5)	100 (10.0)	95.3 (4.0)	108 (10.8)	95.3 (4.0)
LaRC	72 (3.0)	80.2 (3.3)	92 (9.2)	92.5 (3.9)	98 (9.8)	92.5 (3.9)
LeRC	80 (3.3)	80.8 (3.4)	103 (10.3)	92.8 (3.9)	113 (11.3)	92.8 (3.9)
MSFC	67 (2.8)	79.7 (3.3)	86 (8.6)	92.2 (3.8)	91 (9.1)	92.2 (3.8)

HRS - WORK TIME

(DYS) - ELAPSED TIME

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FLEET SIZE SUMMARY

The facing page summarizes the number of small, medium and large systems required to meet the transportation requirements. Dictated by the 1979 - 1982 payload model. As noted on the chart, a maximum of three small systems, four medium systems, and five large systems are required. The driving consideration in determining the quantity of systems required was multiple shipments to support a single Shuttle launch.

FLEET SIZE SUMMARY

SYSTEM \ YEAR QTR	79	1980				1981				1982			
	4	1	2	3	4	1	2	3	4	1	2	3	4
SMALL	1	2	0	2	1	2	3	3	1	2	3	2	3
MEDIUM	0	0	0	4	0	0	4	4	1	0	4	3	4
LARGE	1	0	0	2	5	0	0	2	2	1	2	3	3

COST APPROACH

Hardware cost data was obtained from potential vendors of specific items such as the containers and the instrumentation system (TEMS) and also from Martin Marietta cost estimators. The costs were accumulated as non-recurring (design, tooling) and recurring costs (unit cost, management/systems functions). Following the initial costing activity, several options were assessed in an attempt to reduce the hardware requirements and, therefore, reduce overall cost.

One option that was assessed involved transporting all payloads in the large system. This option was eliminated due the shipping restriction and time involved in using the over-width system for all payload movements.

The other option involved eliminating the medium size system. The medium system was developed specifically for transporting the JPL planetary payloads (PL-13-A and PL-31-A) and Spacelab integrated rack/floor assemblies. When it became apparent that the Spacelab operations baseline did not require shipping the integrated rack/floor assemblies between the launch site and Level IV Sites, the medium system was a good candidate for elimination. The analysis indicated that the Spacelab racks could be accommodated in the small system and the planetary payloads in the large system with minor impact on the required fleet size of the two systems.

Operating costs were obtained from commercial and military transportation concerns for large and small payloads for air and road transport from each Level IV Site to KSC.

The hardware acquisition and systems operating costs were then tabulated for each transportation concept as a basis for selecting the most cost-effective system.

COST APPROACH

HARDWARE COST

- o VENDOR ESTIMATES
 - o INDEPENDENT MMC ESTIMATE
- | | |
|---|----------------|
| { | NON-RECURRING |
| | - DESIGN |
| | - TOOLING |
| | - TEST |
| | RECURRING |
| | - UNIT COST |
| | - MGMT/SYSTEMS |

OPERATIONS COST

- o COMMON CARRIER ESTIMATES
 - AIR } SMALL
 - ROAD } LARGE
 - EACH LEVEL IV SITE

COST EACH CONCEPT

- o ACQUISITION
- o OPERATION
- o MANAGEMENT

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The Guidelines utilized in preparing the system cost estimates are listed on the facing chart. The system was costed in 1976 dollars and based on commercial grade hardware, such as that in use by moving companies, and use of off-the-shelf electronic hardware (TEMS) which has been used in previous commercial and government applications. Design and build to commercial grade results in reduced rates, as follows: Quality Control - 10%; Overhead - 83%; and G&A - 18%. The cost increase involved to build the system in accordance with NASA JSC specification SW-E-002 (which is essentially the same as military standard) is estimated to be 30-50%.

Personnel costs include only those associated with operators supplied by the prime carrier (truck, aircraft), since the number of payload-supplied people is indeterminate at this time. Personnel to manage the transportation program after the system is operational have not been included in the cost.

System-type functions were costed as percentages of the system cost as follows:

Program Management - (through final hardware acquisition)
- 6% of non-recurring total
- 6% of recurring hardware cost total

Logistics - (including cost of spares through 1982)
- 14% of non-recurring total
- 7% of recurring hardware cost total

Systems Engineering - 12% of non-recurring total through hardware acquisition

Sustaining Engineering - 15% of hardware cost per year through final delivery
- 5% of hardware cost per year thereafter

COST GUIDELINES

- o ALL ESTIMATES IN CONSTANT 1976 DOLLARS
- o ACQUISITION COSTS BASED ON COMMERCIAL GRADE HARDWARE RESULTING IN LOWER RATES FOR ENGINEERING, QUALITY, OVERHEAD AND G&A
 - DESIGN TO MILITARY STANDARD ESTIMATED TO INCREASE TOTAL ACQUISITION COST BY 30-50%
- o 10% PROFIT RATE ASSUMED
- o ONLY CARRIER-SUPPLIED PERSONNEL COSTED
- o PROGRAM MANAGEMENT COSTED THROUGH HARDWARE ACQUISITION PHASE ONLY
- o LOGISTICS COST INCLUDES SPARES THROUGH CY 1982
- o SYSTEMS ENGINEERING COSTED THROUGH HARDWARE ACQUISITION
- o SUSTAINING ENGINEERING COSTED THROUGH CY 1982
- o COSTS ESCALATED AT 7% ANNUALLY FROM FY 1977

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ACQUISITION AND OPERATIONS COST - CONCEPT OPTIONS

A summary of the total hardware acquisition and operations cost for each concept (through 1982) is shown on the facing chart. The least costly concept ships small payloads in a standard van with a soft cover (\$652,000) and large payloads in a hard cover on a standard low-boy (\$1,280,000) and costs a total of \$1,932,000.

The only major difference in hardware cost of the small system concepts is the requirement for an additional environmental control unit for air shipments. As noted in the figures, the non-recurring costs are the same for the air and road modes using the same type container (e.g., \$128K for both air and road with a soft cover). The difference between the cost of the small, hard and soft systems is primarily the result of the cost of the covers and cover support system required for the soft system.

The major contributor to the differences in overall concept costs is the high cost of air transport, compared to road transport. The cost-effectivity of the selected over-the-road concept was a major factor in selecting the recommended baseline system.

ACQUISITION & OPERATIONS COST - CONCEPT OPTIONS

SYSTEM SIZE \ COST (K\$)	ACQUISITION			OPS	TOTAL (K\$)
	NON- RECURR	RECURR	TOTAL		
<u>SMALL:</u> SOFT - AIR	128	256	384	361	745
- ROAD	128	242	370	282	652
HARD - AIR	123	275	398	361	759
- ROAD	123	262	385	282	667
<u>LARGE:</u> SOFT - AIR	254	554	808	1,667	2,475
HARD - AIR	267	628	895	1,667	2,562
- ROAD	266	605	871	409	1,280

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SELECTION CRITERIA

After defining conceptual design and operations of the two concepts carried into study Phase II, selection criteria were used to choose the recommended baseline transportation system. The selection criteria used to make the final choice are listed on the facing chart in decreasing order of importance. With the exception of "Total System Cost", the criteria are the same as those used previously to reduce the thirteen concepts to two. In this selection process, the criteria were also weighted to indicate relative importance.

The weighting factors were derived by initially ranking each criterion against every other criterion, one at a time. For example, Total System Cost was ranked against Portal-to-Portal Time and an assessment was made as to which of the two was the most important in terms of discriminating between the system concepts. The criterion judged to be the best discriminator was assigned a score of one (1), and the other criterion received a score of zero (0). After assessing all criteria in this manner, the scores were totaled and the weighting factor is the percentage of the total score assigned to each criterion. The weighting factors are as listed below.

Total System Cost	0.18	Amt. Equipment Required	0.09
Time Portal-To-Portal	0.16	Access for Maintenance	0.07
Security	0.13	Carrier Dedication	0.05
No. Handling Ops.	0.13	Crew Availability	0.05
Induced Environment	0.11	Carrier Availability	0.03

SELECTION CRITERIA

- o TOTAL SYSTEM COST
- o TIME - PORTAL-TO-PORTAL
- o SECURITY - ACCIDENT/VANDALISM VULNERABILITY
 - STATUS MONITORING
- o NUMBER OF PAYLOAD HANDLING OPERATIONS
- o INDUCED ENVIRONMENT
- o AMOUNT OF EQUIPMENT REQUIRED
- o ACCESSIBILITY FOR IN-TRANSIT MAINTENANCE OF TRANSPORTATION EQUIPMENT
- o FEASIBILITY OF CARRIER DEDICATION
- o CREW AVAILABILITY
- o CARRIER AVAILABILITY

SYSTEM RANKING RAW SCORES

Each system concept was ranked against each of the criterion to indicate the most effective system. The system designators across the top of the facing chart indicate system size and container type (i.e. SM/SO indicates the small system using a soft container, LG/H indicates the large system using a hard container, etc.). The "A" and "R" indicate mode of transport - Air or Road, respectively.

Based on the conceptual engineering and cost data generated to this point each concept was ranked against each other with the higher scores indicating a better rank relative to the specific criterion. After deriving the raw scores indicated here, they were normalized using the weighting factors discussed earlier.

SYSTEM RANKING RAW SCORES

CRITERIA \ SYSTEM SIZE	SM/SO		SM/H		M/SO			M/H			LG/SO		LG/H	
	A	R	A	R	A	A	R	A	A	R	A	A	R	
TOTAL COST	2	4	1	3	2	1	3	2	1	3	2	1	3	
TIME (PORTAL-TO-PORTAL)	4	1	4	1	3	3	1	3	3	1	3	3	1	
SECURITY	3	2	4	2	2	3	1	2	3	1	2	3	1	
NUMBER P/L HANDLING OPS	1	2	1	2	1	1	2	1	1	2	1	1	2	
INDUCED ENVIRONMENT	1	3	1	3	2	2	3	2	2	3	2	2	3	
AMT EQUIPMENT REQD	2	4	2	3	2	2	3	2	2	3	2	2	3	
IN-TRANS T-MMSE MAINT ACCESS	1	2	1	2	1	1	2	1	1	2	1	1	2	
DEDICATED CARRIER	1	2	1	2	1	1	3	1	1	3	1	1	3	
CREW AVAILABILITY	1	3	1	3	1	1	2	1	1	2	1	1	2	
CARRIER AVAILABILITY	4	4	4	4	1	1	3	1	1	3	1	1	3	

RANKING SCORE: HIGHEST NUMBER = BEST
 LOWEST NUMBER = WORST

SYSTEM RANKING (SMALL)

The process of combining the raw scores with the weighting factors and the results of that combination are presented on the facing chart. The weighting factors (WF) indicate the relative importance of each criterion as determined through the process described previously.

Note on the chart that the best small system, as indicated by a final score of 2.60, is that one utilizing a soft container over the road (Small, Soft, Road) in a standard van. The next most desirable concept is the SHR (small system with hard container over the road) with a final score of 2.37.

SYSTEM RANKING (SMALL)

CRITERIA	SMALL SYSTEM								
	WT FACTOR	SSA	WE	SSR	WE	SHA	WE	SHR	WE
COST	.18	2	.36	4	.72	1	.18	3	.54
TIME (PORT-TO-PORT)	.16	4	.64	1	.16	4	.64	1	.16
SECURITY	.13	3	.39	2	.26	4	.52	2	.26
NO. P/L HANDLING OPS	.13	1	.13	2	.26	1	.13	2	.26
INDUCED ENVIRONMENT	.11	1	.11	3	.33	1	.11	3	.33
EQUIPMENT REQD	.09	2	.18	4	.36	2	.18	3	.27
IN-TRANSIT T-MMSE MAINT ACCESS	.07	1	.07	2	.14	1	.07	2	.14
DEDICATED CARRIER	.05	1	.05	2	.10	1	.05	2	.10
CREW AVAILABILITY	.05	1	.05	3	.15	1	.05	3	.15
CARRIER AVAILABILITY	.03	4	.12	4	.12	4	.12	4	.12
			<u>2.10</u>		<u>2.60</u>		<u>2.05</u>		<u>2.37</u>

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SYSTEM RANKING (LARGE)

The process just described for the small system was repeated for the large system as shown on the facing chart. The most effective system indicated is the LHR, or Large system with payloads in a Hard container transported over the Road. The second choice for the larger payloads is in a soft container via air (score of 1.83).

SYSTEM RANKING (LARGE)

CRITERIA	WT FACTOR	LARGE SYSTEM					
		LSA	WE	LHA	WE	LHR	WE
COST	.18	2	.36	1	.18	3	.54
TIME (PORTAL-TO-PORTAL)	.16	3	.48	3	.48	1	.16
SECURITY	.13	2	.26	3	.39	1	.13
NO. P/L HANDLING OPS	.13	1	.13	1	.13	2	.26
INDUCED ENVIRONMENT	.11	2	.22	2	.22	3	.33
EQUIPMENT REQD	.09	2	.18	2	.18	3	.27
IN-TRANSIT T-MMSE MAINT ACCESS	.07	1	.07	1	.07	2	.14
DEDICATED CARRIER	.05	1	.05	1	.05	3	.15
CREW AVAILABILITY	.05	1	.05	1	.05	2	.10
CARRIER AVAILABILITY	.03	1	.03	1	.03	3	.09
			<u>1.83</u>		<u>1.78</u>		<u>2.15</u>

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TRANSPORTATION SYSTEM HARDWARE

The recommended baseline system resulting from this study consists of two systems, both of which utilize road transportation as baseline, but which are also compatible with air transportation.

A summary of the hardware required for the recommended small and large transportation systems is presented on the facing chart. One of each item indicated is required, per system, with the exception of the two adapters supplied as Spacelab GSE. Two of the pallet adapters (vertical) would be required when shipping two pallets in the same large container; up to six rack adapters could be required for multiple rack shipments in a single van.

The ancillary equipment listed is of the type available commercially by rent/lease agreement. The Small Transportation System requires one escort vehicle when transporting a payload and the Large System requires two escort vehicles whenever the container is moved.

The next several charts describe the system hardware in greater detail. Payload to system interfaces are defined in Appendix B of this document.

TRANSPORTATION SYSTEM HARDWARE

		TRANSPORTATION MMSE															ANCILLARY			
HARDWARE	SYSTEM SIZE	ADAPTERS																		
		SOFT COVER	HARD COVER	PLATFORM	AUTO ENL	AUTO CENTER	PALLET (H)	PALLET (V) *	RACK *	APU/ECS	TEMS	SLING KIT	TIE-DOWN KIT	DUST BAG	HYDROSET	TRACTOR	VAN	LOW-BOY	ESCORT VEH	
SMALL		X		X	X	X			X		X	X	X	X		X	X		X	
LARGE			X	X	X		X	X		X	X	X	X	X	X		X		X	

* SPACELAB GSE

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SYSTEM HARDWARE - SMALL SYSTEM

A wide range of payloads must be accommodated by the transportation system. Those defined in the current payload model range from 225 lb to near 10,000 lb and from 3.3 ft in diameter to over 14 ft. The conceptual system was designed to accommodate as many payloads as possible with the most cost-effective system. The detailed analyses indicated that two different sized systems (designated Small and Large) could handle the payloads most efficiently. The next several charts illustrate the hardware required for each system. More detailed interface definition is provided in Appendix B.

The small system accommodates payloads up to 7' 2-1/2" diameter and up to 20' long. Environmental control is provided by the carrier, (i.e., standard air-ride tractor/van assembly). The payload environment will be monitored at all times. Critical parameters will be connected to an alarm system allowing immediate attention to any out-of-tolerance parameter.

The payload will be secured to the transport platform by one of a series of adapters. The adapter will isolate the payload from the shipping platform.

The shipping platform is manufactured in segments to accommodate the full range of payload lengths defined above.

The payload is covered by a static-free bag which maintains cleanliness during transportation. An additional soft, reusable cover, which provides additional protection and insulation is also used in the small system. The cover is supported and held away from the payload surface and is used at all times when outside the test facilities. This cover is also segmented and protects the payloads on the segmented platforms.

The payload, container and transport environment monitor system will be transported in a standard 8' wide road van and will travel with an escort vehicle from center to launch site.

Recommended System - Small Payloads (Up to 7.2' Wide x 7.5' high x 20' Long)

Carrier - Standard environmentally controlled air-ride van

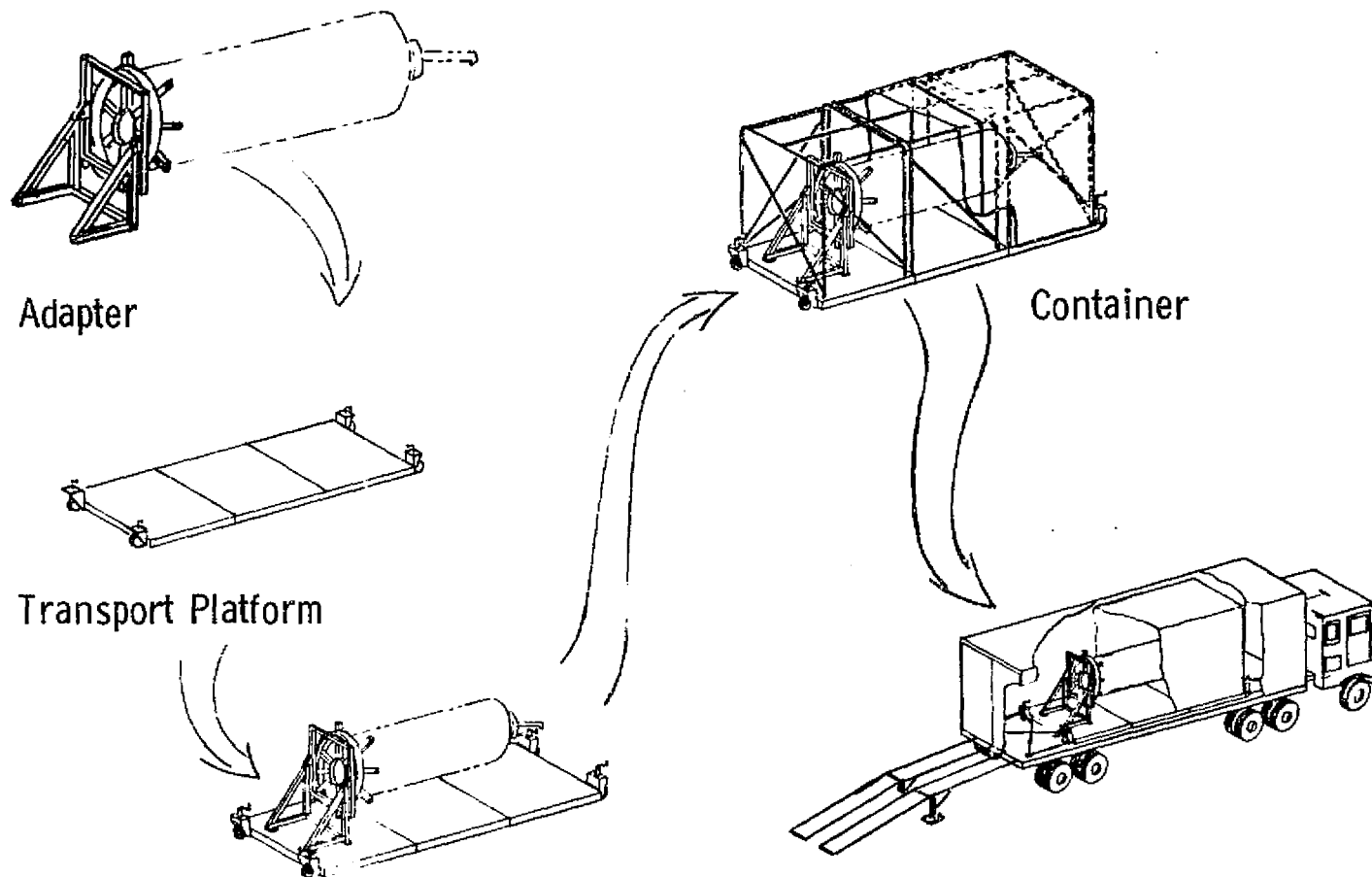
Container - Segmented transport platform and soft cover

Payload Adapters - End Mount; center mount; Spacelab rack (GFP)

Auxiliary Power, Environmental Control - Supplied by van

Environmental Monitor - Transportation Environment Monitor system (TEM); (temperature, relative humidity, shock, power)

SYSTEM HARDWARE - SMALL SYSTEM



SOFT CONTAINER - SMALL SYSTEM

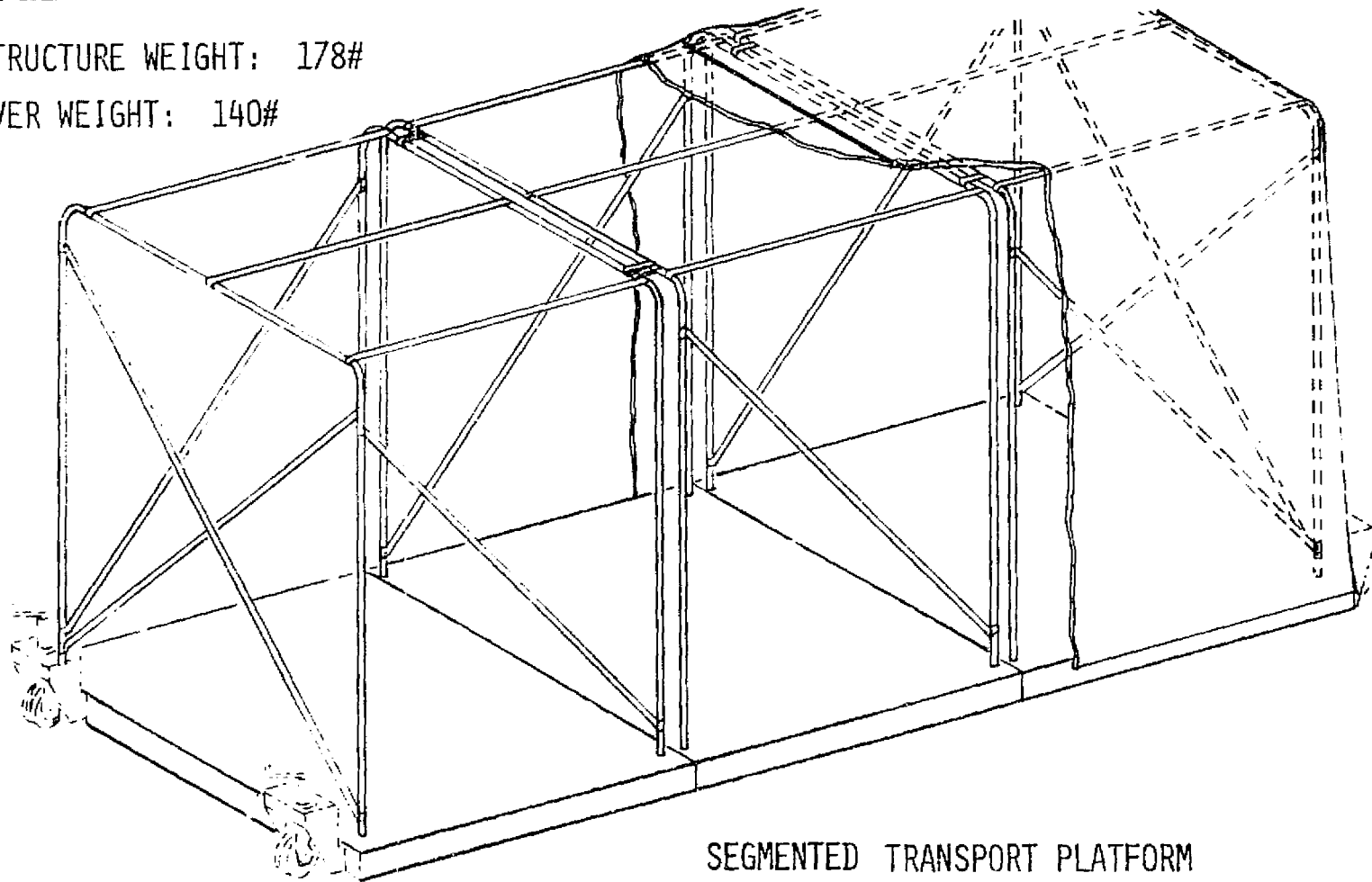
The small system utilizes platform segments of 7'4" wide x 7'6" long x 6" high. The basic structure is of steel construction weighing approximately 3000 lbs for a three-segment, 22'6" long platform. The segments attach and self-align easily to allow quick reconfiguration. Tie down rings and lifting slugs will be provided on the platform structure. Adjustable casters are removable for ease of reconfiguring. A universal mounting pattern will be employed to adapt the various adapters to the platform or platform segments. The floor is insulated to help maintain proper environmental control. Tubular metal supports keep the soft, 1"-thick insulated canvas cover from contacting the payload surfaces.

The soft cover will have lifting straps to allow removal by crane or by rolling back to expose the support structure. An interface panel will exist to facilitate all associated cabling and service lines.

SOFT CONTAINER - SMALL SYSTEM

STRUCTURE WEIGHT: 178#

COVER WEIGHT: 140#



SEGMENTED TRANSPORT PLATFORM

	LENGTH	WIDTH	HEIGHT
CONTAINER	22'6"	7'4"	8'8"
PLATFORM			
SEGMENT	7'6"	7'4"	6"

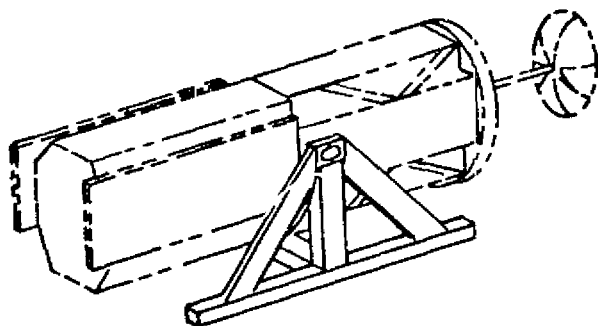
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PAYLOAD ADAPTERS - SMALL SYSTEM

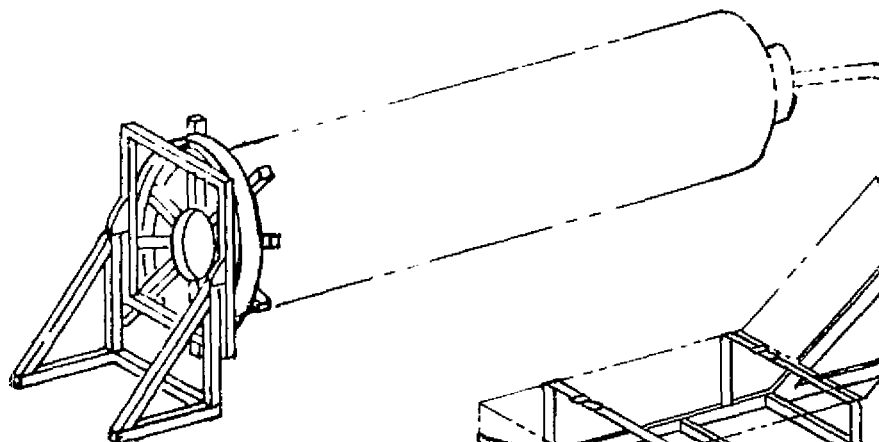
Three types of adapters are required to utilize the presently defined payload flight interfaces for transportation. These adapters will accommodate payloads in the 225-4000 lb class, from 3'4" to 7'6" diameter and from 3'4" to 16'10" long. The center-mounted adapter will accommodate automated payloads utilizing the GSFC flight support system.

The end-mounted horizontal adapter will accommodate automated and automated/IUS-type payloads with flight mounting interfaces on the end. The spider portion of the adapter can be mounted directly to the platform for small, vertical payloads. The rack adapter will accommodate Spacelab racks without floor assemblies. The adapter is existing GFP (ESRO) hardware. The rack adapters can be joined to accommodate double racks. All of the adapters will be shock-isolated from the transport platform.

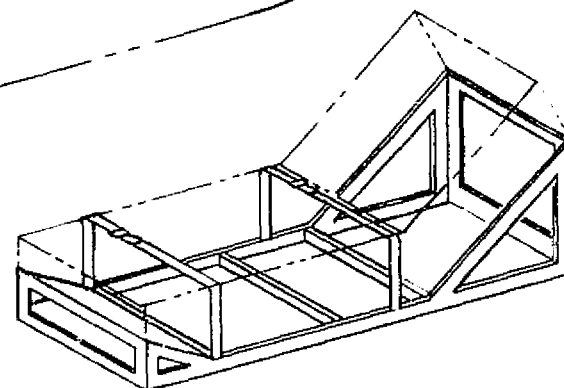
PAYLOAD ADAPTERS - SMALL SYSTEM



Center Mounted
Adapter



End Mounted
Adapter
(Horizontal)



Rack Adapter - GFP

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Payloads being transported will be monitored with sensors at various locations to provide recorded engineering data to determine the acceptability of the payload shipment.

The system will monitor and record as a function of time the following: Temperatures (internal and external), relative humidity (internal and external), payload accelerations, carrier accelerations and payload power levels. (This study does not indicate an operational need for recording external temperature and relative humidity, although there will be indicators on the containers to monitor in realtime internal and external temperature and relative humidity.)

The system will alarm out-of-tolerance limits of internal temperature less than 65 degrees F, more than 75 degrees F, internal relative humidity less than 30 percent and greater than 50 percent, shock and acceleration levels on the payload and carrier adjusted to payload limitations and loss of APU and/or payload power. The TEMS will operate for a minimum of four hours on battery power from the APU battery if power is interrupted from the APU.

Shock and acceleration will be measured using nine sensors mounted triaxially. The sensor characteristics are as follows: $\pm 2\%$ sensitivity; 10 millivolts/G; frequency range 1-1000 Hz; operating temperature range -100 degrees F to + 250 degrees F. Each sensor is approximately 1" x 1" x 1".

Slow-response sensors to measure temperature, relative humidity and spacecraft power have the following characteristics: Temperature, -10 degrees F to +160 degrees F @ ± 2 Degrees F accuracy; size, 3-1/4" x 4-1/2". Relative humidity, 13 percent to 99 percent; size, 3-1/4" x 4-1/2".

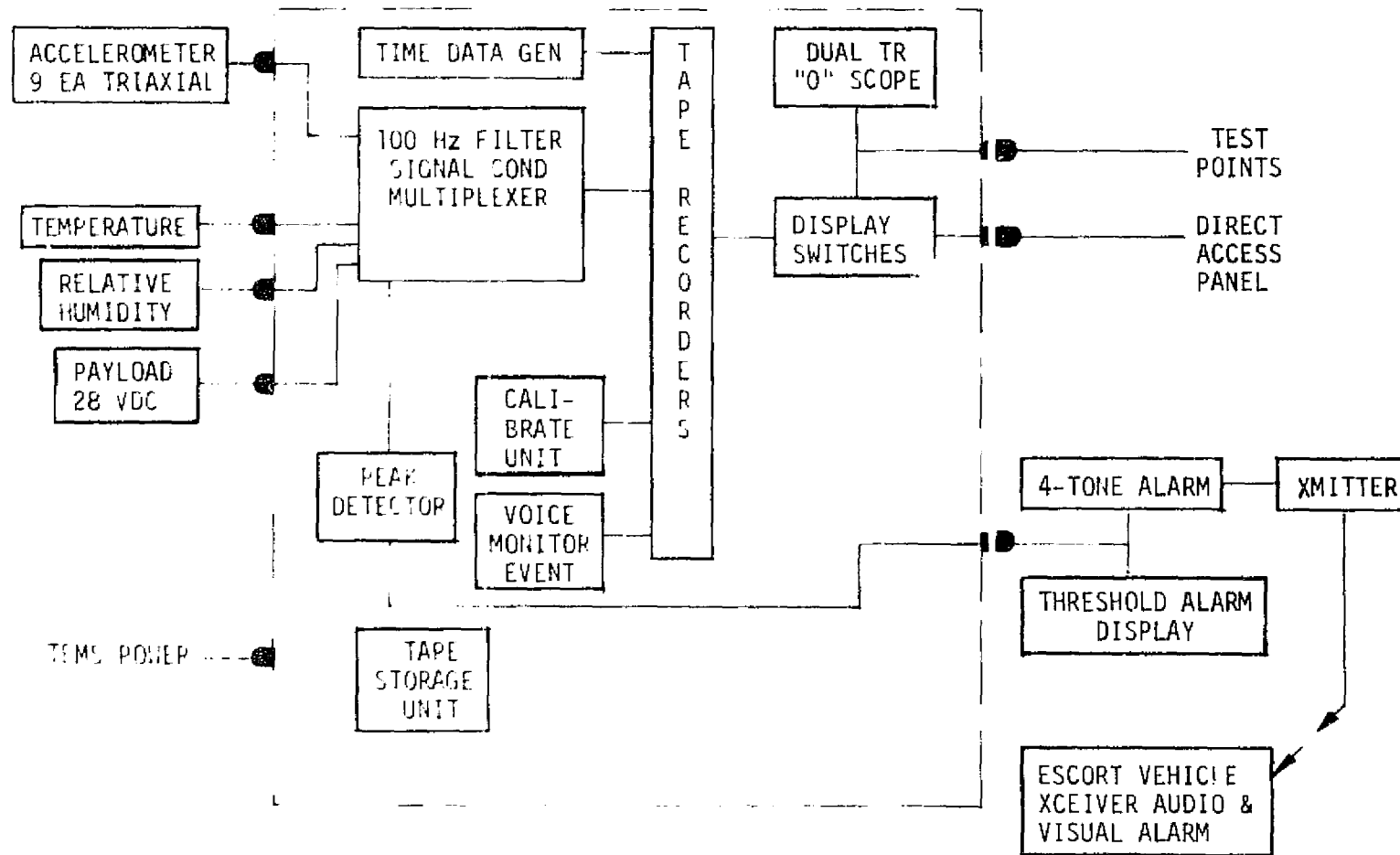
The alarm system provides visual and audio displays using four tones and four light display elements. The alarm signal will be transmitted to receivers in the prime carrier and the escort vehicle. The TEMS monitor and memory unit analog tape recorder operates at 1-7/8 IPS, uses 3600' tape reels (8" diameter x 1/2" wide tape) each of which records for 6.4 hours. A time/date generator is used for correlation of data to events with an accuracy of $\pm 1 \times 10^{-7}$ days/day error.

Test points and a direct access connector will be provided for trouble shooting purposes. By use of a selector switch any desired channel may be measured or viewed on the oscilloscope.

The packaging of the TEMS will allow its operation in adverse weather conditions. All boxes are fiberglass construction with weatherproof connectors on the cabling.

This system is designed to use off-the-shelf hardware as much as possible and has the capability of being expanded, if required.

TRANSPORTER ENVIRONMENT MONITOR SYSTEM (TEMS)



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SYSTEM HARDWARE - LARGE SYSTEM

The large system will accommodate payloads up to 14'4" wide, 10.8' in height and up to 20' long. Environmental control will be provided by a separate APU/ECS system secured to the bed of the carrier (standard air-ride tractor and air-ride low-boy trailer).

The payload will be monitored at all times. Critical parameters will be monitored utilizing a warning system allowing immediate attention on any out-of-tolerance parameter.

The payload will be secured to the transport platform by one of a series of adapters. The adapters will isolate the payload from the shipping platform.

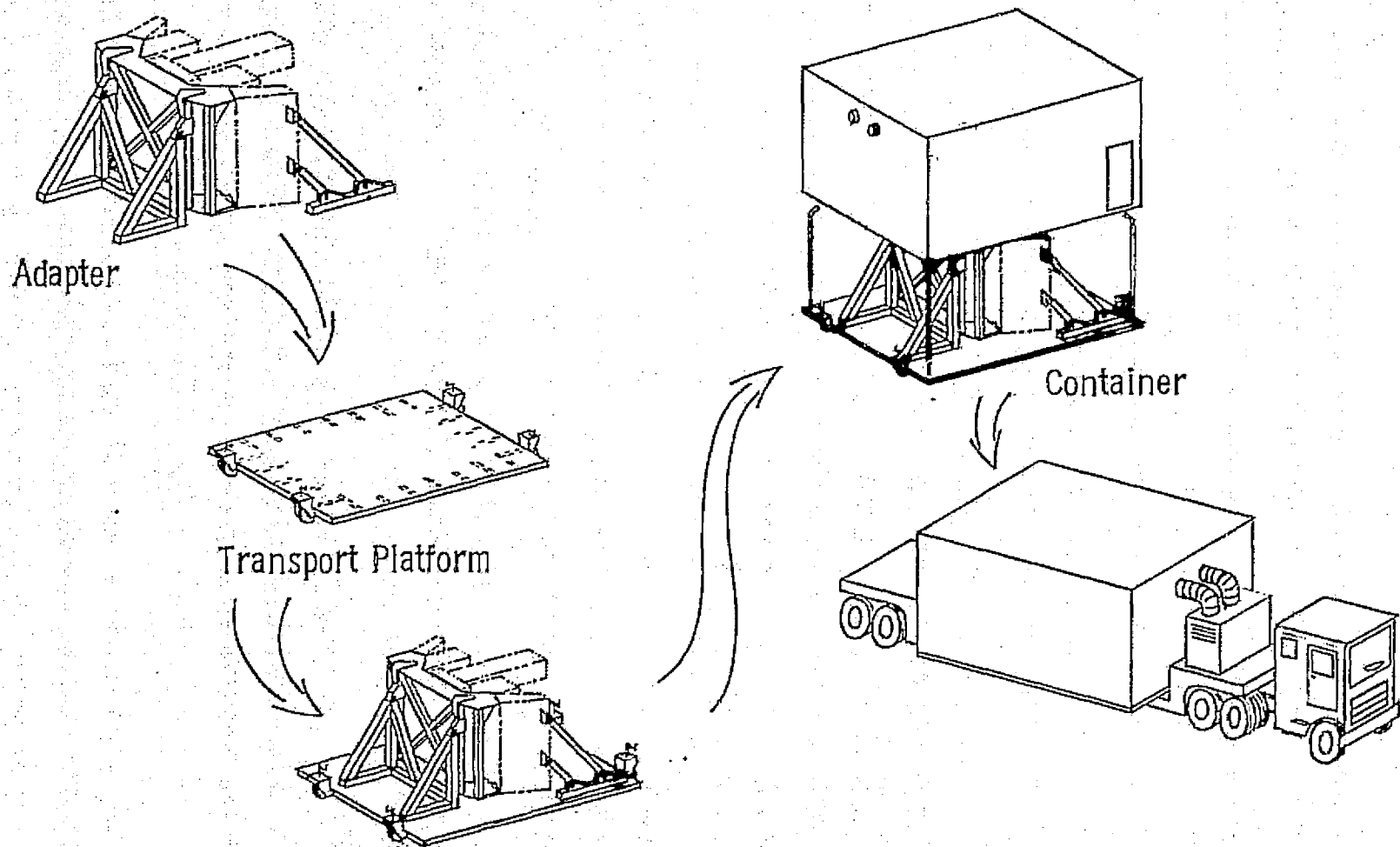
The payload is covered by a static-free bag which maintains cleanliness during transportation. In addition, the hard cover provides the necessary insulation and security for transporting over the road.

The payload hard container, transportation monitor and APU/ECS will be transported on a standard, 8' wide low-boy trailer using two escort vehicles.

Recommended System - Large Payloads

Carrier	Standard Air Ride Low-Boy Trailer
Container	Hard Cover
Payload Adapters	End Mount Spacelab Pallet-Vertical (GFP) Spacelab Pallet-Horizontal
Auxiliary Power, Environmental Control	Combined APU/ECS Unit
Environmental Monitor	Transportation Environment Monitor System (TEMS) - Temperature - Relative Humidity - Shock - Power

SYSTEM HARDWARE - LARGE SYSTEM



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HARD CONTAINER - LARGE SYSTEM

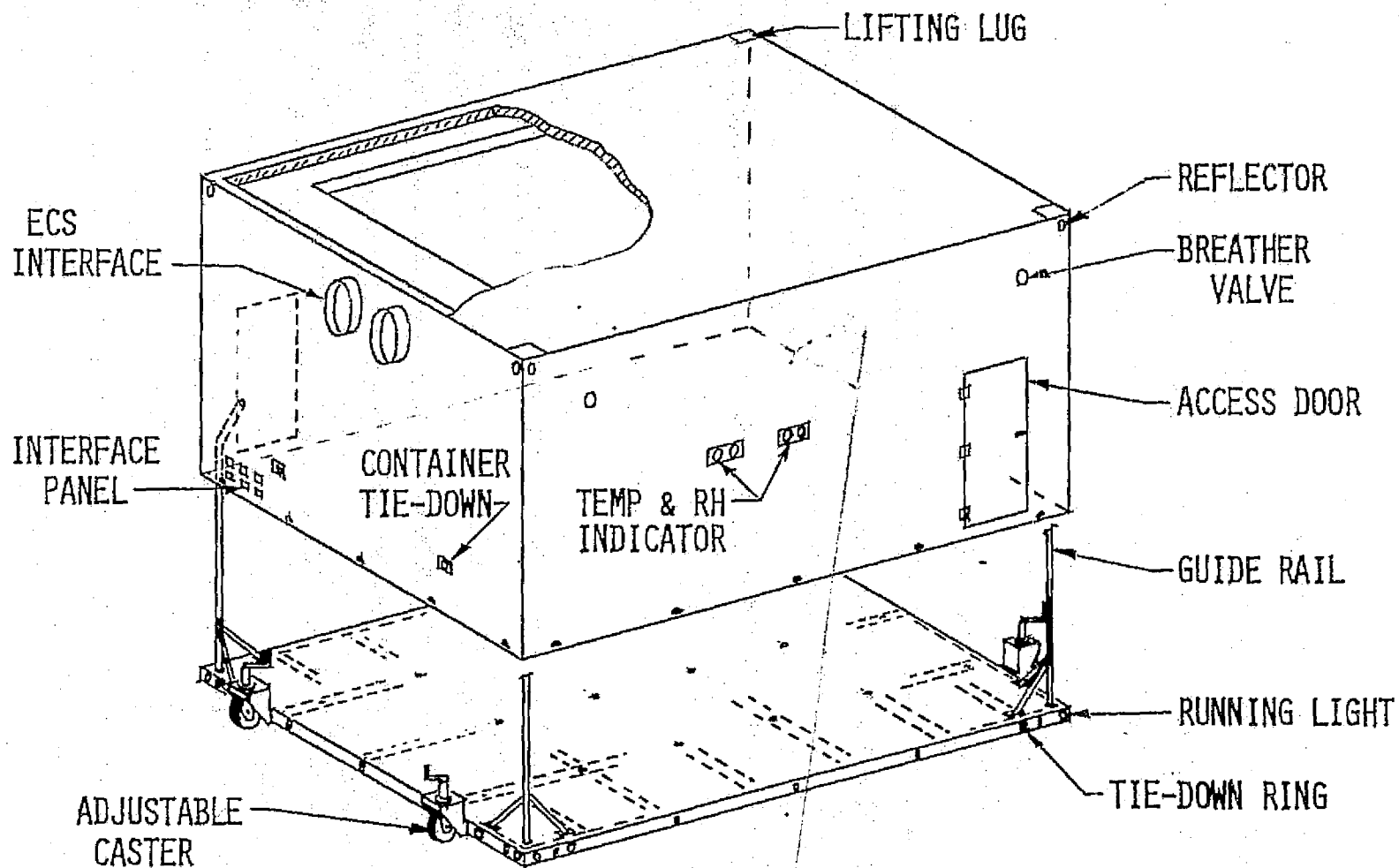
The large container base is 6" high x 15' wide x 22'6" long, is of steel construction and weighs approximately 5500 lbs. The floor is insulated with polyurathane foam to help maintain the proper environmental control. A universal mounting pattern to mount the various payload adapters is provided. Adjustable casters facilitate ease of movement of the platform or container.

A guiderail on each corner assists in removing or installing the cover. Lights and reflectors are provided to meet ICC regulations for over-the-highway movement. Tie-down rings will be provided at intervals to accommodate the loads expected to be seen using a maximum of 9"G's" forward deceleration and 4-1/2 "G's" forward deceleration and 4-1/2 "G's" side and up.

The cover is constructed of insulated material 2" thick with a metal frame supporting the basic construction. The inside surfaces are fiberglass and the outside is aluminum sheet. Lift points are provided at each corner of the basic frame. Access doors 3' x 4' are provided on two sides to allow access to payloads. ECS ducting; inlets and manifold distribution system are utilized for conditioned air distribution in the container from the ECS.

Tie-down rings are provided around the cover; an interface/feed-through panel provides payloads services as required and temperature and humidity gages to monitor internal and external measurements are mounted on the side. Large vacuum/pressure dessicated breather valves are on the corners for preventing pressure or vacuum buildup. Latches at the base of the cover secure it to the transport platform during transit. The cover size is 11'4" high x 15' wide x 22'6" long (outside dimensions).

HARD CONTAINER - LARGE SYSTEM



	LENGTH	WIDTH	HEIGHT
CONTAINER	22' 6"	15'	11' 10"
PLATFORM	22' 6"	15'	6"

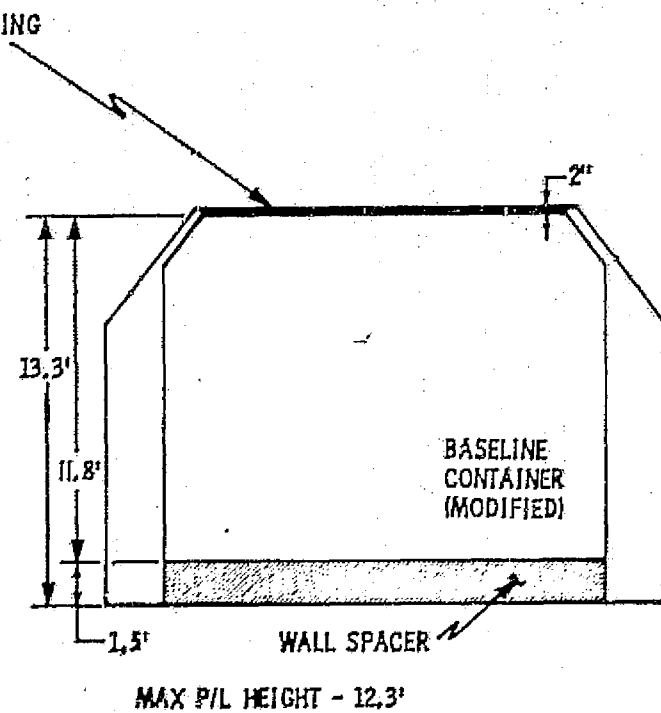
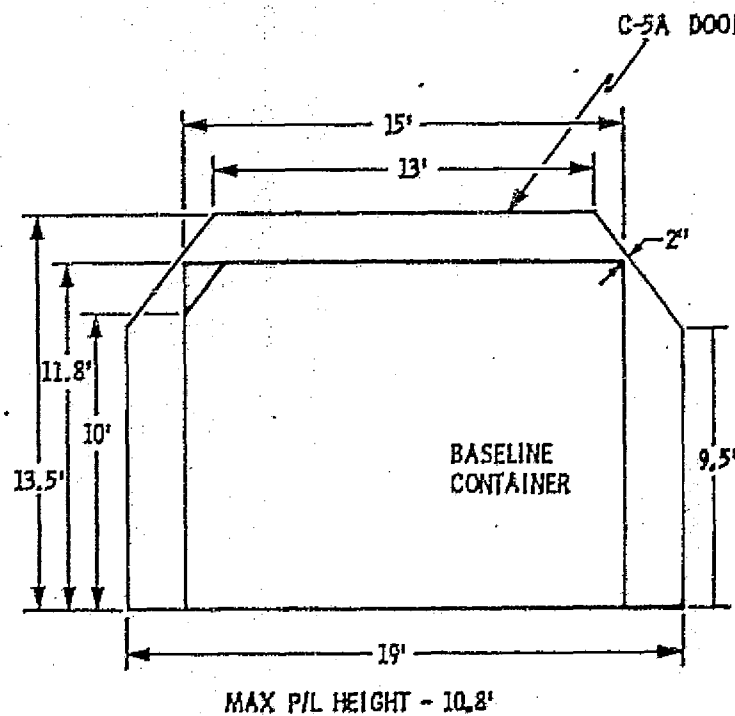
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LARGE CONTAINER - AIR LIFT CONFIGURATION OPERATIONS

The large container was limited to a height of 10.8 ft to stay within the overall height restriction of 13.5 ft for over the road travel. In order to take full advantage of the height of the C-5A door, and to allow payloads up to 12.3 ft to be shipped in the large container, the modification shown on the facing chart was defined.

The upper corners of the container can be configured to match the angle of the C-5A door opening which will allow the top of the container to come within 2 inches of the door opening. This allows the container to be 13.3 ft high and increases the allowable payload by 18 inches, to 12.3 ft. The container wall spacer can be bolted on the bottom of the container to provide the extra height for C-5A transport and removed for transporting payloads to the launch site over the road.

LARGE CONTAINER - AIR LIFT CONFIGURATION OPTIONS



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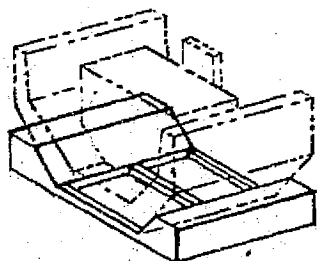
PAYLOAD ADAPTERS - LARGE SYSTEM

Two types of adapters are required for transporting payloads in the large system. (A third type, pallet adapter (vertical), is GPP from the Spacelab program).

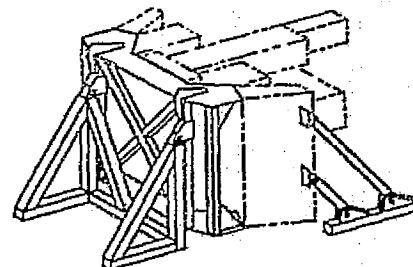
The end-mounted adapter will accommodate the larger (up to 14.3' wide x 10.8' high) payloads. The adapter is adjustable to allow variations in the mounting pattern as described for the end mounted adapter in the small system.

Analysis of the requirements for the Spacelab pallets indicates a potential requirement for two adapters; one for pallets where the overall height does not exceed 10.8'; and one for rotating the pallet 90 degrees if the overall height exceeds 10.8'. Pallet rotation is required to stay below the 13'6" road height and the C5-A cargo door opening.

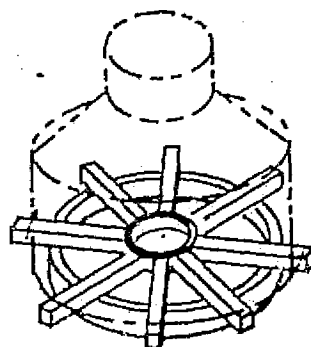
PAYLOAD ADAPTERS - LARGE SYSTEM



Pallet Adapter
(Vertical)- GFP



Pallet Adapter
(Horizontal)



End Mounted Adapter
(Vertical)

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PALLET ROTATION SEQUENCE

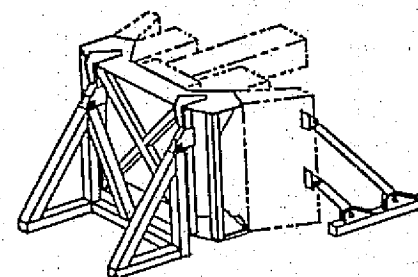
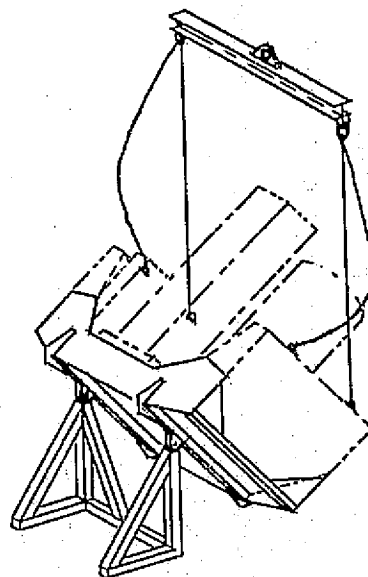
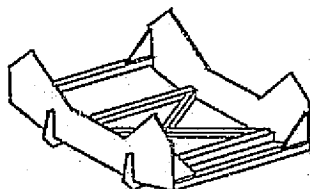
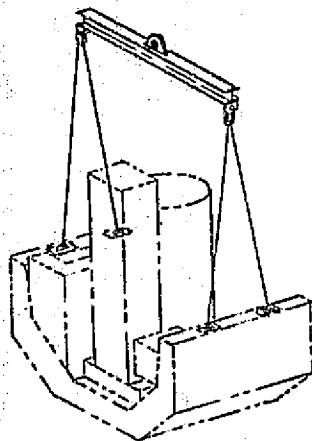
The decision to rotate Spacelab pallets 90 degrees so that the pallet is transported in the same position as when launched in the Shuttle resulted from two considerations. First, the study was directed at accommodating the maximum number of the payloads defined in the model and at the same time limiting the overall height of carrier, payload and container to 13'6". The second consideration in system design was to minimize (eliminate if possible) the impact of the transportation system on payload design. Since the pallet-mounted Spacelab payloads could grow to fill the Shuttle payload bay envelope of 15', the standard-size transportation system could not accommodate such payloads if transported vertically.

The solution to this problem was to rotate the pallets (with experiments) as described above, such that the 15' dimension becomes the transported length and the 9'8" pallet length becomes the transported height.

The sequence of the rotation is as shown on the facing chart. The pallet trunnion fittings are replaced by transportation lift/tie-down fittings and the pallet is then placed into the adapter. The adapter is bolted to the pallet, using the pallet train holes on the ends of the pallet and the payload is lifted again and placed on the rotation/adapter support fixture which is mounted on the transport platform. The adapter support fixture is located relative to the adapter such that the pallet keel fitting is not disturbed. The adapter/support fixture interface point is located off the pallet/payload center of gravity so that as the crane lowers the pallet, the assembly will rotate to the desired position. After pallet rotation the adapter is secured to the support fixture and forward supports are attached between the trunnion points and the platform as additional supports.

The sling to lift and rotate the pallet is part of the T-MMSE sling set.

PALLET ROTATION SEQUENCE



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AUXILIARY POWER UNIT/ENVIRONMENTAL CONTROL UNIT

Various voltages and levels of power are required in the operation of the Environmental Control System, Transport Environment Monitor System and Payload Systems during transportation. A gasoline-powered motor generator provides continuous power of 208 VAC, 3-Phase 50/60 Hz for the ECS; 28 VDC to a battery-augmented system for operating the TEMS and to provide power to the payload, as required, and 115 VAC 50/60 Hz as service power. The 28 VDC battery system could function for a minimum of four hours under a 500-watt load.

To simplify the handling and operational problems, the APU, ECS and auxiliary batteries will be combined in a single housing.

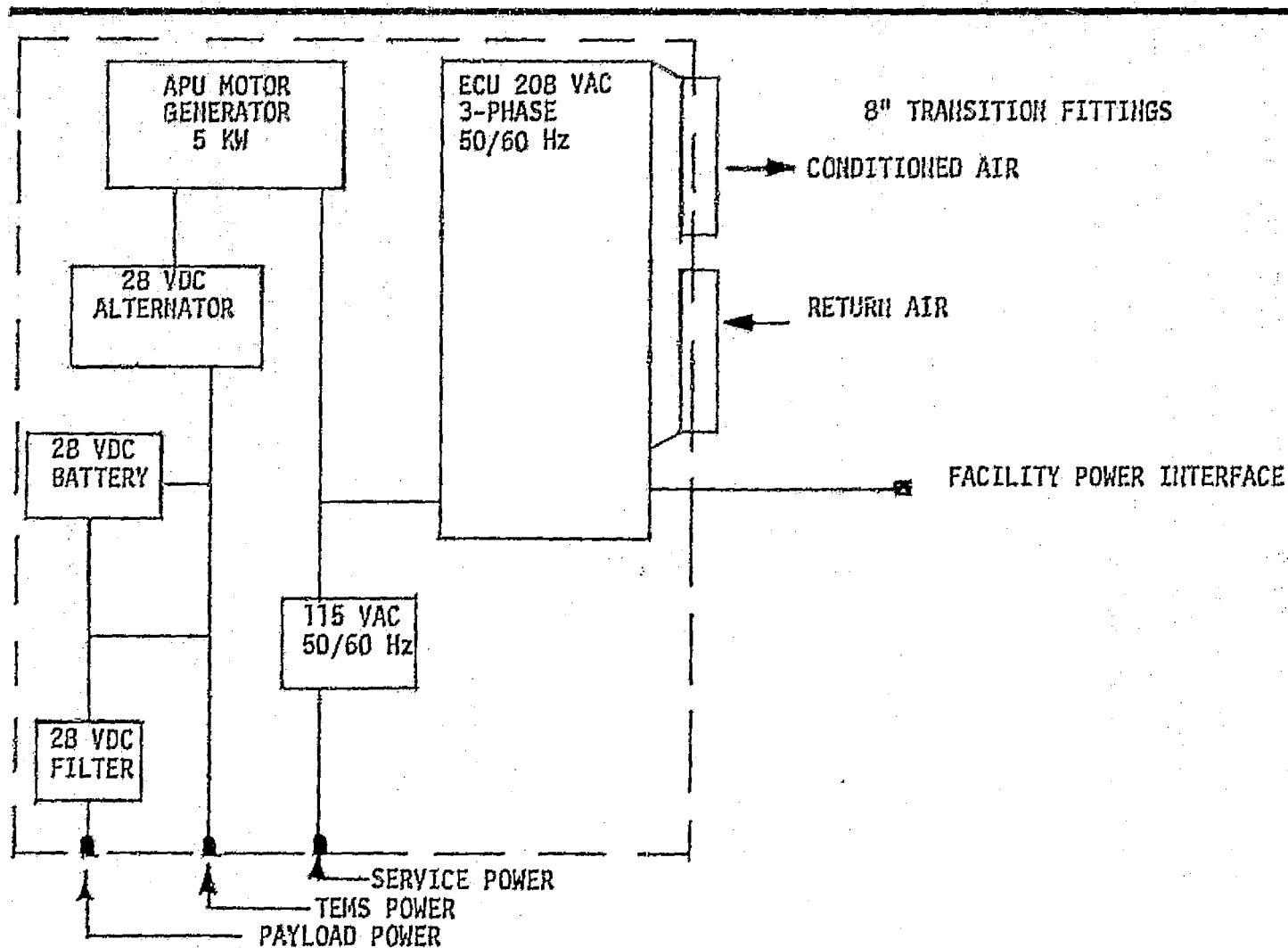
The ECS will provide and maintain 70 +/-5 degrees F temperature in an ambient range of -40 degrees F to +120 degrees F and a 40 +/-10% relative humidity at all times. A filtration system will provide cleanliness control of conditioned air. The following is the capacity of the ECS:

Cooling Capacity	24,000 BTU
Heating Capacity	4-1/2 KW
Power (Required to Operate)	208 VAC, 3-Phase 50/60 Hz
Conditioned Air Supply	800 CFM
Max Operating Ambient	120 Degrees F
Min Operating Ambient	-40 Degrees F
APU/ECS Weight	1800 Lbs
APU Output Rating	5 KW
APU/ECS Dimensions	48"H x 48"W x 90"L

The ECS has 8" transition duct fittings for connections to the large container. Capability exists for ECS operation on facility power of 208 VAC, 3-Phase, 50/60 Hz.

- Note: 1) The Transport Environment Monitor System (TEMS) used in the large system is the same as system described previously for the small system;
- 2) The requirement to maintain temperature is from document JSC 07700, Vol XIV, Rev D; relative humidity requirement is from the payload requirements document.
- 3) The most probable failure mode of the ECS is the compressor. The estimated cost of providing redundancy by use of a dual stage compressor is \$8,000 per unit. This cost is not included in the cost data on Page 106. In the event of APU failure, the ECU can be operated on standard facility power.

AUXILIARY POWER UNIT/ENVIRONMENTAL CONTROL UNIT



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FLEET SIZE SUMMARY

The data on the facing chart reflects the fleet size (number of systems) required for both the small and large systems on a quarterly basis. The fleet size was derived as discussed previously, by assessing both usage density (time required per shipment times the number of shipments per quarter) and the number of shipments required to support a single Shuttle flight. The requirement for multiple, simultaneous shipments in support of one flight turns out to be the driving consideration in most cases. The boxed numbers indicate the first time the maximum number of systems is required to support the existing mission model. Looking beyond 1982 (-572 Mission Model), there is no apparent increase in fleet size required to support the peak Shuttle traffic of forty flights per year. This is true because the pre-1983 fleet size was driven by multiple shipments and will accommodate a full Shuttle load of pallets (5) or racks (15).

As the post-1982 payload and cargo definitions mature, additional transportation systems could be required to accommodate shipment of more than three auto or auto/IUS payloads simultaneously, or a problem could develop if the usage density of either size system for multiple, simultaneous shipments increases above the presently defined level.

FLEET SIZE SUMMARY

SYSTEM \ YR QTR	79	1980				1981				1982			
	4	1	2	3	4	1	2	3	4	1	2	3	4
SMALL	1	2	0	2	1	2	③	3	1	2	3	2	3
LARGE	1	0	0	2	⑤	0	0	2	2	1	2	3	3
NO. PAYLOADS	2	1	1	1	2	4	3	3	3	6	7	6	4

- o TOTAL PAYLOAD SHIPMENTS - 146

POST-1982 REQUIREMENTS

- o NO APPARENT IMPACT ON TRANSPORTATION FLEET SIZE
 - FLEET SIZE TO ACCOMMODATE THROUGH 1982 DRIVEN BY MULTIPLE SHIPMENTS FOR SINGLE FLIGHT AND SIZED TO ACCOMMODATE MAX LOAD OF 5 PALLETS OR 15 RACKS
- o POTENTIAL IMPACTS CAUSED BY:
 - MORE THAN 3 AUTOMATED ON SAME FLIGHT
 - USAGE DENSITY OF MULTIPLE SHIPMENTS

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TOTAL TRANSPORTATION SYSTEM COST - RECOMMENDED SYSTEM

The recommended intersite transportation system is estimated to cost \$3,400,000. This figure is based on the costing guidelines discussed previously and includes the hardware cost for three (3) complete small systems and five (5) large systems, as well as the estimated cost of operating the system through calendar year 1982. The only item not included in this total are the costs of the organization to manage the system after final hardware delivery and payload and MMSE personnel costs. MMSE personnel requirements are estimated at one or two people per trip to supply expertise on the APU/ECS and TEMS. The number of payload personnel required to accompany the shipment to KSC is undefined at this time.

The cost drivers exerting the greatest influence on conceptual system selection were: 1) The relatively high cost of aircraft, particularly those required for the large payloads (C-130, C-141, C-5A); 2) The need to transport cargo elements of the same flight simultaneously (i.e., 5 pallets on a single Shuttle flight require 5 simultaneous large system shipments; and 3) Requiring design of conform with MIL-STD would increase cost by an estimated 30%-50%.

TOTAL TRANSPORTATION SYSTEM COST - RECOMMENDED SYSTEM

COST (K\$) \ FISCAL YR	1980	1981	1982	1983	TOTAL (K\$)
<u>ACQUISITION</u>					
SMALL					
NON-RECURRING	168	-	-	-	168
RECURRING	211	113	-	-	324
LARGE					
NON-RECURRING	349	-	-	-	349
RECURRING	317	509	-	-	826
	<u>1,045</u>	<u>622</u>			<u>1,667</u>
<u>OPERATIONS</u>					
SMALL	43	156	161	49	409
LARGE	51	153	301	98	603
	<u>94</u>	<u>309</u>	<u>462</u>	<u>147</u>	<u>1,012</u>
PROGRAM MANAGEMENT	63	37	-	-	100
LOGISTICS	109	44	-	-	153
SYSTEMS ENGRG	62	-	-	-	62
SUSTAINING ENGRG	157	187	31	31	406
	<u>391</u>	<u>268</u>	<u>31</u>	<u>31</u>	<u>721</u>
TOTAL (K\$)	<u>1,530</u>	<u>1,199</u>	<u>493</u>	<u>178</u>	<u>3,400</u>

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DETAILED ACQUISITION COST - RECOMMENDED SYSTEM

The cost data on the facing chart provides a more detailed breakdown of the cost of acquiring the hardware comprising the small and large systems. The costs are provided in constant 1976 dollars. Depending on when the hardware is bought, appropriate inflationary factors must be added.

The single most costly item of the entire system is the Transporter Environment Monitor System (TEMS). The non-recurring development cost for this system is estimated at \$172,000 and the unit cost at \$53,000 per copy. Due to the relatively small size of the system, it is feasible that the system could be air freighted to the user at reasonable cost, thereby reducing the actual use time during each payload transportation operation and therefore reducing the number of systems required.

Several of the items, including TEMS, the sling kit and the end mount payload adapter are used in both the large and small systems. The design, tooling, and test of such systems is applicable to both size systems and is therefore shown as a cost item against only one system.

DETAILED ACQUISITION COST - RECOMMENDED SYSTEM

T-MSE ITEM	NON RECURRING	RECURRING (UNIT COST)	QTY REQ'D	TOTAL COST 1976 \$(K)
<u>Small System</u>				
Soft Cover	20.0K	2.2K	3	26.6
Soft Cover Support	19.3K	2.3K	3	26.2
Transport Platform	20.0K	6.6K	3	39.8
Adapters				
End Mount (Vertical)	13.4K	3.1K	3	22.7
Center Mount	29.7K	3.8K	3	41.1
End Mount (Horiz.)	25.6K	3.8K	3	37.0
Spacelab Rack	GSE	-	-	0
Sling Kit	**	5.1K	3	15.3
TEMS	**	53.0K	3	159.0
Tie Down Kit	-	0.7K	3	2.1
				<u>369.8</u>
<u>Large System</u>				
Hard Cover	32.6K	21.4K	5	139.6
Transport Platform	24.8K	6.5K	5	57.3
Adapters				
End Mount	++	5.1K	5	25.5
Pallet (Horiz)	28.4K	3.6K	5	46.4
Pallet (Vert.)	GSE	-	-	0
Sling Kit	7.6K	5.1K	5	33.1
TEMS	172.0K	53.0K	5	437.0
Tie Down Kit	-	1.3K	5	6.5
Hydro Set	-	15.0K	5	75.0
APU/EGS	1.0K	10.0K	5	51.0
				<u>871.4</u>

Note: (1) All costs shown in constant 1976 dollars.

(2) ** Non-recurring cost included in non-recurring cost number shown for large system

(3) ++ Non-recurring cost included in non-recurring cost number shown for small system

BASELINE SYSTEM ESCALATION IMPACT

The cost impact on the T-MMSE due to escalation is shown below. Each year shows the 76 dollar cost versus the escalated cost. Escalated cost is figured at 7% annually. If the total complement of hardware is purchased at the initial buy for both large and small systems, a considerable savings will result.

The cost figure shown for fiscal year 1980 (\$1.53M) is the cost of acquiring two small systems and two large systems and includes the total cost for non recurring, recurring, program management, logistics, systems engineering and sustaining engineering costs from the beginning of the engineering design concepts thru FY 1980.

The FY 1981 recurring cost is for one additional small system and three additional large systems to complete the total buy. If the one additional small system and three large systems were acquired at the same time as the FY 1980 buy, a savings of \$178,000 could be realized.

BASELINE SYSTEM ESCALATION IMPACT

COST (K\$)	FY	1 9 8 0		1 9 8 1		1 9 8 2		(1ST QTR) 1 9 8 3		T O T A L	
		\$76	ESCAL	\$76	ESCAL	\$76	ESCAL	\$76	ESCAL	\$76	ESCAL
<u>ACQUISITION</u>											
SMALL SYSTEM											
NON-RECURRING		128	168	0	0	0	0	0	0	128	168
RECURRING		161	211	81	113	0	0	0	0	242	324
LARGE SYSTEM											
NON-RECURRING		266	349	0	0	0	0	0	0	266	349
RECURRING		242	317	363	509	0	0	0	0	605	826
		<u>797</u>	<u>1045</u>	<u>444</u>	<u>722</u>	0	0	0	0	<u>1241</u>	<u>1657</u>
<u>OPERATIONS</u>											
SMALL SYSTEM		33	43	111	156	108	161	30	49	282	409
LARGE SYSTEM		<u>39</u>	<u>51</u>	<u>109</u>	<u>153</u>	<u>200</u>	<u>301</u>	<u>61</u>	<u>98</u>	<u>409</u>	<u>603</u>
		<u>72</u>	<u>94</u>	<u>220</u>	<u>309</u>	<u>308</u>	<u>462</u>	<u>91</u>	<u>147</u>	<u>691</u>	<u>1012</u>
PROGRAM MGMT		-	63	-	37	-	0	-	0	-	100
LOGISTICS		-	109	-	44	-	0	-	0	-	153
SYSTEMS ENGRG		-	62	-	0	-	0	-	0	-	62
SUSTAINING ENGRG		-	<u>157</u>	-	<u>187</u>	-	<u>31</u>	-	<u>31</u>	-	<u>406</u>
			<u>391</u>		<u>268</u>		<u>31</u>		<u>31</u>		<u>721</u>
TOTAL		869	1530	664	1199	308	493	91	178	1932	3400

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PEAK LAUNCH RATE COST OF OPERATIONS

The facing chart indicates an estimated transportation system operations cost of \$1.322 million to support the peak launch rate of 40 flights per year. This figure is based on the estimated operations cost of \$462,000 to provide the level of payload transportation required to support 16 launches in 1982.

The cost of operating the system in 1982 was multiplied by 2.5 ($\frac{40}{16}$) and then escalated at an annual rate of 7% to account for inflation. It is assumed that the number of shipments required to support any given flight in 1984 is roughly equivalent to those required in the Preliminary Estimate Payload Model utilized for this study.

PEAK LAUNCH RATE COST OF OPERATIONS

FY	1980	1981	1982	1983 (1ST QTR)	1984 (PEAK)
OPERATIONS COST	94	309	462	147	1322
NO. STS LAUNCHES (NON-DOD)	4	8	16	3	40

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INTERSITE TRANSPORTATION SYSTEM SCHEDULE

The schedule shown indicates need dates and development schedules for both the small and large transportation systems; how the schedule meshes with the first six shuttle flights; and at the bottom shows the estimated expenditure of funds required for each fiscal year. The first system of each size is required for use at the end of FY 1979.

The design, development and testing of major items constituting the small system are estimated to require 15 months and the sling set and tie-down kit requires about 10 months. The second small system is required the end of the first quarter FY 1980, and the third by the middle of FY 1981.

The design, development and test cycle for the large system container and adapters is estimated to require two years. The TEMS cycle requires 15 months; APU/ECS, 12 months and the sling set and tie-down kit, 10 months. The second large system is required at the end of the third quarter FY 1980, and the third, fourth and fifth systems are required at the end of FY 1980.

Detailed schedules for both systems are on the following two charts.

NOTE: The schedule was developed specifically to accommodate the payload traffic defined in the preliminary estimate payload model. The first payload shipments required in that model are to support OFT #3, scheduled for launch in the first quarter of FY 1980. If support of OFT #2 is required, a large transportation system would be required to transport the Spacelab pallet in the fourth quarter of FY 1979, and the development of the large system would have to begin one quarter earlier than shown, i.e., the beginning of the fourth quarter, FY 1979.

INTERSITE TRANSPORTATION SYSTEM SCHEDULE

MILESTONES	FY	1977				1978				1979				1980				1981				1982				1983			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
OFT FLIGHTS										1	2	3	4	5	6														
SMALL SYSTEM																													
CONTAINER								▽					△	②				③											
ADAPTERS								▽																					
TEMS								▽																					
SLING SET & TIE-DN KIT									▽																				
													△ *																
LARGE SYSTEM			▽ *																										
CONTAINER				▽									△		②	③	4	5											
ADAPTERS				▽																									
TEMS								▽																					
APU/ECS									▽																				
SLING SET & TIE-DN KIT									▽																				
TOTAL DISBURSED (K\$)									359				1077				984			340					493				147 (1)

NOTES:

- △ FIRST SYSTEM NEED DATE
- SUBSEQUENT SYSTEM NEED DATE
- (1) COST FOR 1ST QTR, FY 1983

- ▽ START DATE
- * OFT 2 SUPPORT

SMALL INTERSITE TRANSPORTATION SYSTEM

The facing chart schedules the design, development and test cycle for the elements of the small transportation system.

The basic 15-month cycle is applicable to all system elements with the exception of the sling set and tie-down kit, which is estimated to require 10 months. One month is allocated for predelivery system testing (through acceptance tests) and an additional month for post-delivery receiving inspection.

A standard 3-month Advertise and Award cycle is provided for all system elements.

The first system need date is at the beginning of the 1st quarter of FY1980, the 2nd system by the 2nd quarter of FY 1980 and the final system by the 3rd quarter of FY 1981.

SMALL INTERSITE TRANSPORTATION SYSTEM																													
MILESTONES	FY	1977				1978				1979				1980				1981				1982				1983			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4				
						DESIGN CONCEPTS								△	○					◇									
						DESIGN																							
CONTAINER										AAA																			
- PLATFORM										FABRICATE																			
- SOFT COVER										TEST																			
- COVER SUPPORT										RECEIVING INSP																			
PAYLOAD ADAPTERS																													
- SPIDER																													
- SPIDER SUPPORT																													
- CENTER MOUNT																													
- RACK (GFP)																													
TEMS																													
SLING SET & TIE-DOWN KIT						DESIGN CONCEPTS																							
						DESIGN																							
										AAA																			
										FABRICATE																			
										TEST																			
										RECEIVING INSP																			

NOTES: △ 1ST SYSTEM NEED DATE
○ 2ND SYSTEM NEED DATE
◇ 3RD SYSTEM NEED DATE

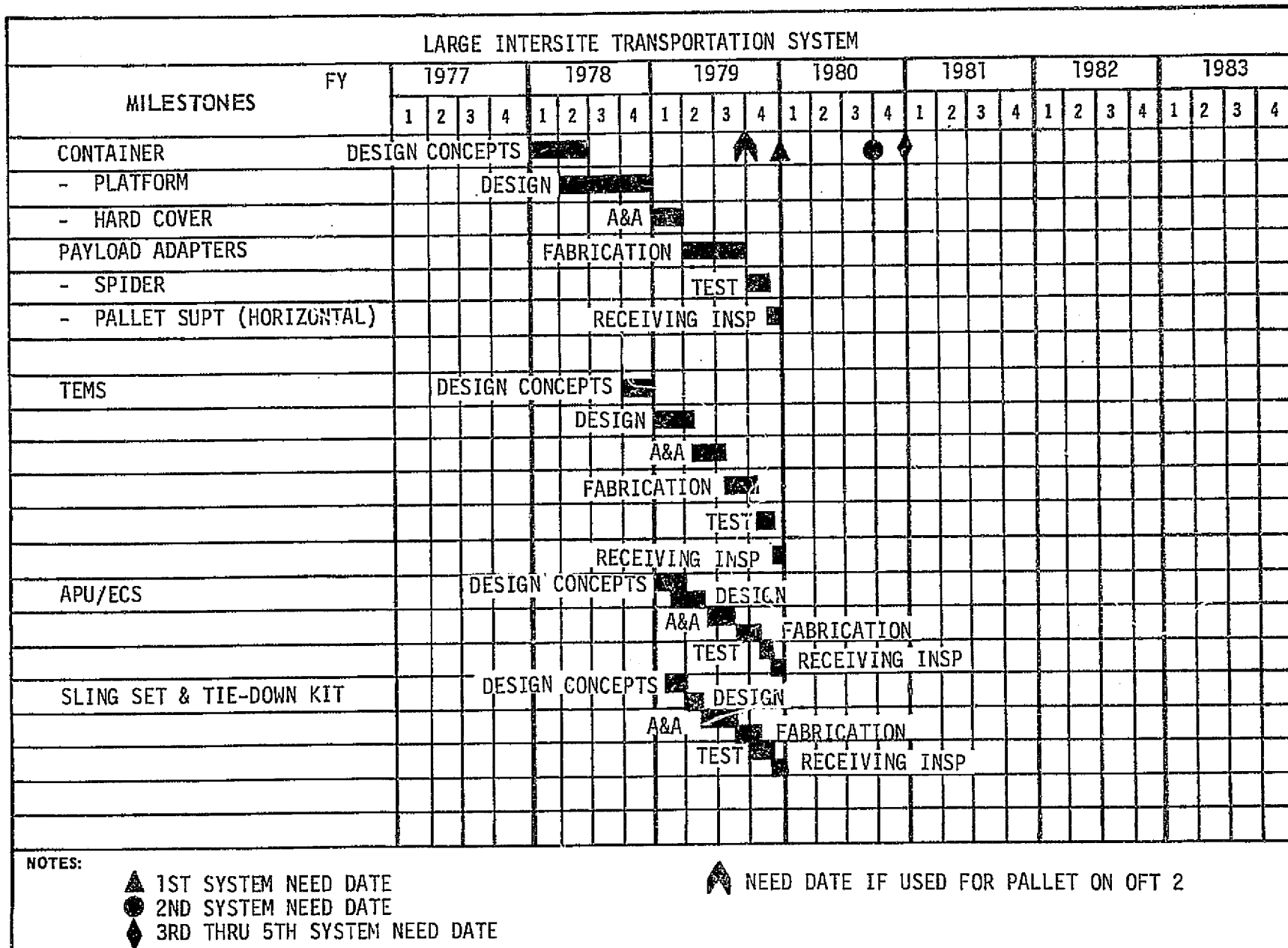
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LARGE INTERSITE TRANSPORTATION SYSTEM

The design, development and test schedule for the large transportation system is shown on the facing chart. Two years are required for the hard container and payload adapters. This includes six months to complete the design concepts, nine months for detail design, a three-month Advertise and Award cycle, six months for fabrication, two months for predelivery testing (through acceptance tests) and one month for post-delivery inspection.

The same cycle for TEMS would require 15 months; APU/ECS, 12 months and 10 months for the sling set and tie-down kit.

If the first system must support OFT 2 the need date is the 4th quarter FY 1979. If the first system must support the model (starts with OFT #3) the need date is the 1st quarter of FY 1980 with the second required by the 4th quarter of FY 1980 and the third through the fifth system needed the 1st quarter FY 1981.



NOTES:

- ▲ 1ST SYSTEM NEED DATE
- 2ND SYSTEM NEED DATE
- ◆ 3RD THRU 5TH SYSTEM NEED DATE

▲ NEED DATE IF USED FOR PALLET ON OFT 2

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SMALL SYSTEM CAPABILITY

The small transportation system, using a standard 8'-wide air-ride van, can accommodate all of the payloads in the mission model up to and including those 7.2' wide by 7.5' high and approximately 20' long. Excluding LDEF, only three automated spacecraft cannot be accommodated in the small system. The small system also accommodates up to six spacelab racks at a time.

SMALL SYSTEM CAPABILITY

- o MAXIMUM ENVELOPE ACCOMMODATED
7.2' WIDE x 7.5' HIGH x (APPROX) 20' LONG
- o ALL SMALL PAYLOADS IN MISSION MODEL CAN BE ACCOMMODATED
 - GAMMA RAY EXPLORER
 - SOLAR MAX MISSION
 - STORMSAT-A
 - SPHINX
 - EXPLORER
 - GRAVITY PROBE-B
 - RADIATION BUDGET SATELLITE
 - LUNAR POLAR ORBITER
 - DISASTER WARNING SATELLITE
 - FOREIGN GEOSYNC METEOROLOGICAL
 - TRAFFIC MANAGEMENT
 - SPACELAB RACKS

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LARGE SYSTEM CAPABILITY

The large transportation system, using a standard 8' wide air ride drop center low boy can accommodate payloads up to and including those 14.3' wide X 10.8' high and approximately 20' long.

The large transportation system can accommodate all of the payloads in the mission model, including the small payloads, with the exception of the LDEF (14' diameter x 30' long) and pallet trains with experiments which exceed an overall height (including pallet) of 10.8'.

LARGE SYSTEM CAPABILITY

o MAXIMUM ENVELOPE ACCOMMODATED

14.3' WIDE x 10.8' HIGH x (APPROX) 20' LONG

o PAYLOADS ACCOMMODATED

- SINGLE SPACELAB PALLET WITH EXPERIMENTS (15' ENVELOPE)
- TWO SPACELAB PALLETS WITH OVERALL HEIGHT 11'
- PIONEER JUPITER ORBITER PROBE
- JUPITER SWINGBY OUT-OF-ELIPTIC
- BIOMEDICAL EXPERIMENT SCIENTIFIC SATELLITE (BESS)
- IUS (ASSUMING 8' DIA x 8' LONG, AS DEFINED)
- ALL PAYLOADS ACCOMMODATED IN SMALL SYSTEM

o PAYLOADS NOT ACCOMMODATED

- ASSEMBLED LONG-DURATION EXPOSURE FACILITY (LDEF)
- TRAIN (2 OR MORE) OF SPACELAB PALLETS EXCEEDING 11' HIGH

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INTERSITE TRANSPORTATION PROGRAMMATICS

Schedule and fund allocation requirements for the intersite transportation system are summarized on the facing chart. Based on a need date of October, 1979, for both systems, the Phase B DDT&E activity must begin in October, 1977, for the large system hardware and in July, 1978, for the small system hardware. If OPT Flight 2 is to be supported, the large system must be available three months earlier and DDT&E started in July, 1977.

Development of the detailed system specifications must be completed early in FY 1977 to allow nine months for the normal procurement cycle.

The funding allocations required to support system acquisition and operation are shown on the lower half of the chart. The acquisition funds (T-MMSE Row) are shown in the year the funds must be allocated to support the activities required the following year. For example, the \$359,000 shown in FY 1977 must be allocated in 1977 to support the DDT&E activities in FY 1978. The \$31,000 shown as T-MMSE cost in FY 1980 and 1981 represents the cost of sustaining engineering activities in FY 1981 and 1982 after hardware delivery. The \$147,000 allocated in 1982 is the estimated cost of system operations through the first quarter of FY 1983. (December 1982).

INTERSITE TRANSPORTATION PROGRAMMATICS

FISCAL YEAR ACTIVITY	1977	1978	1979	1980	1981	1982	
	1977	1978	1979	1980	1981	1982	
DEVELOP SPEC							
PROCUREMENT CYCLE							
DDTE							
COST (\$K)							
T-MMSE	359	1077	890	31	31	-	2388
OPERATIONS	-	-	94	309	462	147	1012
TOTAL	359	1077	984	340	493	147	3400

▽ - 506 AUTHORITY

△ - 1st NEED DATE

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COST-EFFECTIVITY

Past payload programs have traditionally developed transportation equipment as part of the program. Each transportation system has restricted applicability and normally must be replaced, or at best modified, for subsequent programs. Total cost of all transportation activity has been estimated to cost between 6% and 10% of the total program cost (PAD). It is very difficult to define what portion of that transportation cost is equivalent to the costs defined for the recommended system, however, the example on the facing chart, illustrates the potential cost-effectivity of a multi-use system.

The transportation system for the GSFC Applications Technology Satellite (ATS) cost approximately \$180,000. The system was developed specifically for the ATS and supported only one launch of a single payload even though the system was used for five shipments of the spacecraft and test articles.

The recommended transportation system is applicable to a full range of payloads and can be used through the next decade. The cost of developing and using the system is \$7,400 per shipment using the small system and \$24,000 per shipment using the large system. These costs are based on spreading the acquisition costs through 1991. In any event, the hardware will be acquired in 1981 and subsequent shipments would include only operations cost and system management costs.

COST-EFFECTIVITY

PAST PROGRAMS

NEW TRANSPORTATION SYSTEM EACH PAYLOAD

- LIMITED APPLICATION
- RELATIVELY HIGH COST

ATS TRANSPORTATION SYSTEM - \$180,000
- FIVE USES, ONE PAYLOAD

RECOMMENDED BASELINE

MULTI-USE SYSTEM - 1979 THROUGH 1982

COST PER SHIPMENT

- IF ACQUISITION COST AMORTIZED ONLY THROUGH 1982
 - SMALL SYSTEM - \$18,000 PER SHIPMENT
 - LARGE SYSTEM - \$45,000 PER SHIPMENT
- IF ACQUISITION COST AMORTIZED THROUGH 1991*
 - SMALL SYSTEM - \$7,400 PER SHIPMENT
 - LARGE SYSTEM - \$24,000 PER SHIPMENT

* SYSTEM MANAGEMENT COST NOT INCLUDED

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OUTSIZED PAYLOAD TRANSPORTATION SYSTEM

Analysis of the Preliminary Estimate Payload Model and the existing 1983-91 Traffic Model (NASA TM X-64751, Rev. 2 dated January 1974) indicates several apparent requirements for an outsize payload transportation capability. The first outsized payload requiring transportation to KSC is the fully assembled LDEF currently scheduled for flight in the fourth quarter of 1979.

Transport of the integrated Spacelab from KSC to WTR also requires an outsized system by 1983. A potential requirement also exists to support Shuttle landings at the alternate and contingency landing sites. This capability could be required as early as 1979.

OUTSIZED PAYLOAD TRANSPORTATION SYSTEM

ASSUMPTIONS

- o EXISTING 1983-91 MISSION MODEL
- o IUS NOT OUTSIZED
- o FULLY ASSEMBLED LDEF IS OUTSIZED
- o SPACELAB LEVELS II & III INTEGRATION AT KSC

CONCLUSIONS

- o SYSTEM REQUIRED TO TRANSPORT LDEF IN 1979
- o SYSTEM REQUIRED FOR INTEGRATED SPACELAB TRANSPORT FROM KSC TO WTR IN 1983
- o SYSTEM REQUIRED TO SUPPORT LANDINGS AT ALTERNATE AND CONTINGENCY SITES FROM PROGRAM OUTSET
- o CHANGE IN ASSUMPTIONS IMPACTS NEED DATE

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INTERSITE TRANSPORTATION STUDY - CONCLUSIONS/RECOMMENDATIONS

Road transportation of Shuttle payloads in the 1979-82 time frame is the most cost effective system. The transportation system can accommodate all of the payloads in the preliminary estimate payload model (1979-1982), with the exception of the assembled LDEF. The two major restrictions on payload shipments both concern Spacelab hardware - only one pallet segment can be shipped, per system, if the experiments extend to the maximum fifteen-foot diameter, and the traffic analysis does not include use of the large system for transporting integrated rack/floor assemblies. The rack/floor assemblies can be physically accommodated in the large system, but since such shipments were groundruled out, the number of large systems provided was not based on such usage. Additional systems might be required if the groundrule is changed.

The cost for system hardware acquisition and operations through 1982 is estimated to be approximately \$3.5 million. The transportation fleet size of three (3) small and five (5) large systems will support the maximum launch rate of forty per year. This extrapolation is based on the assumption that the 1979-1982 cargos are typical of later cargos. If several multiple shipments are required within a short time span (e.g., several pallet-only missions within one quarter), additional system could be required.

Road transportation is recommended for all Shuttle payloads using the small and large systems as defined in detail previously. All of the system hardware has been designed to be compatible with air transport in the event of contingencies which may arise.

It is also recommended that NASA procure the T-MMSE defined in the study and contract for carrier services as required. This will allow NASA to maintain control of the transportation system scheduling and hardware to ensure on-time payload delivery.

To support Shuttle flights as now defined, the procurement of the large system should begin no later than October, 1977, and the small system by July, 1978. It is recommended, on the basis of all payloads being delivered to KSC through 1982, that the depot for the transportation MMSE be located at KSC.

INTERSITE TRANSPORTATION STUDY - CONCLUSIONS/RECOMMENDATIONS

CONCLUSIONS

- ROAD TRANSPORTATION OF SHUTTLE PAYLOADS MOST COST-EFFECTIVE
- SYSTEM CAN ACCOMMODATE ALL PAYLOADS IN MODEL, WITH EXCEPTION OF ASSEMBLED LDEF
- ROM SYSTEM COST (ADJUSTED FOR INFLATION) FOR ACQUISITION AND OPERATION THROUGH 1982 IS APPROXIMATELY 3.5M
- THREE (3) SMALL AND FIVE (5) LARGE SYSTEMS WILL ACCOMMODATE FORTY (40) STS LAUNCHES, PER YEAR, ASSUMING TYPICAL CARGO MAKE-UP

RECOMMENDATIONS

- USE ROAD TRANSPORTATION FOR INTERSITE MOVEMENT OF SHUTTLE PAYLOADS THROUGH 1982
 - DESIGN IS COMPATIBLE WITH AIR TO ACCOMMODATE CONTINGENCIES
- NASA BUY T-MMSE, LEASE CARRIERS
- START DESIGN OF LARGE SYSTEM BY OCTOBER, 1977
- START DESIGN OF SMALL SYSTEM BY JULY, 1978
- DESIGNATE KSC AS DEPOT FOR TRANSPORTATION MMSE

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STUDY LIMITATIONS

The study objectives were to develop detailed requirements, conceptual design definition, cost and acquisition plans for a recommended baseline system of MMSE for intersite transportation of Shuttle payloads from 1979 through 1982. The study was necessarily limited by specific guidelines, constraints and assumptions to ensure that the study was performed on schedule and within funding constraints. Conclusions and recommendations were based on these limitations, some of which are shown on the facing chart.

Physical Size - This study was to define a system for transporting standard size payloads. This resulted in limiting the overall height of the system (carrier plus container) to 13.5 ft. Oversize payloads were not assessed and cannot be accommodated in the system as defined.

Payload Definition - The basic source of payload requirements data was the SSPD. This data was supplemented by personal contact with the payload community which resulted in a good set of requirements as the payloads are presently defined. However, it is anticipated that as more detailed payload analyses are performed on specific payloads, additional MMSE may be identified.

Payload Model - The payload transportation traffic and the fleet size required to handle the traffic is highly sensitive to the payload model. Although the system hardware definition is not particularly sensitive to the payload model, the number of systems required is highly sensitive to the cargo makeup and launch schedule.

MMSE Definition - The hardware definitions provided by this study are conceptual only. It should be recognized that although the concepts are based on engineering analyses, additional detailed analyses are required on the system before firm recommendations could be made regarding MMSE design, development, and operation.

STUDY LIMITATIONS

- PHYSICAL SIZE OF SYSTEM
 - 13.5' OVERALL HEIGHT
 - OVERSIZE PAYLOADS NOT ACCOMMODATED
e.g. FULLY INTEGRATED SPACELAB, LARGE
AUTOMATED (LDEF, ST), ETC.
- PAYLOAD DEFINITIONS
 - DETAILED PAYLOAD ANALYSES MAY
IDENTIFY MORE T-MMSE.
- PAYLOAD MODEL
 - FLEET SIZE SENSITIVE TO CARGO MAKEUP
AND FLIGHT SCHEDULE.
- T-MMSE DEFINITION
 - CONCEPTUAL DESIGN ONLY
 - DETAILED ANALYSES REQUIRED TO SUPPORT
FIRM RECOMMENDATIONS ON DESIGN,
DEVELOPMENT AND OPERATION.

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RECOMMENDED ADDITIONAL EFFORT

The study results provide definition of a baseline intersite transportation system for Shuttle payloads, ROM cost estimates, and the required acquisition schedule. The items listed on the facing chart are areas of additional activity required to develop and operate the system.

A User's Handbook is required in the near future to provide data to potential users regarding system capability. An outline of the handbook and preliminary definition of the payload-to-system interfaces are included in the Appendix to this document to serve as the initial input to potential users.

Phase B definition of the MMSE items for the large system should be initiated by October 1977, and the small system by July 1978.

RECOMMENDED ADDITIONAL EFFORT

- DEVELOP USERS HANDBOOK FOR STANDARD PAYLOAD TRANSPORTATION SYSTEM
- INITIATE PHASE B ON LARGE SYSTEM - OCTOBER 1977
 - HARD CONTAINER
 - PAYLOAD ADAPTERS
SPACELAB PALLET
END MOUNT (AUTO)*
 - AUX PWR UNIT/ENVIRONMENTAL CONTROL SYSTEM
 - TRANSPORT ENVIRONMENT*
MONITOR SYSTEM
 - SLING KIT*
 - TIE DOWN KIT
- INITIATE PHASE B ON SMALL SYSTEM - JULY 1978
 - SOFT CONTAINER
 - PAYLOAD ADAPTERS
CENTER MOUNT (AUTO)
 - TIE DOWN KIT

*PHASE B DESIGN APPLICABLE TO BOTH LARGE AND SMALL SYSTEMS

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1. Preliminary Estimate Payload Model, G. Esenwein, NASA/HQ, Dec 15, 1975.
2. Multi-use Mission Support Equipment Final Report, Vol. I through VI, NAS 8-30847, NASA/MSFC, April 1975.
3. Multi-use Mission Support Equipment, Final Report, Vol. I through III, NAS8-31615, NASA/MSFC, June 1976.
4. Space Shuttle System Payload Accommodations. Volume XIV. Revision D. JSC 07700. November 26, 1975.
5. Spacelab Payload Accommodation Handbook. NASA/ESRO. May 1975.
6. Summarized NASA Payload Descriptions, Automated Payloads, Level A Data. July 1975.
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9. Payload Descriptions, Volume II, Sortie Payloads, Level B Data. July 1975.
10. Flight Support System for Earth Observation Satellites. SD-74-A-0057, NASA/GSFC, Contract NAS5-23203, Rockwell International, June 1974.
11. The October 1973 Space Shuttle Traffic Model. NASA TMX-64751, Rev 2. January 1974.
12. "572 Traffic Model." NASA/MSFC Working Papers.
13. Spacelab Transportation Study, 40A88001, Rev. A, NASA/MSFC, July 31, 1975.
14. IUS Ground Operations Plan, DRAFT, SP-PAY-T, NASA/KSC, June 1976.
15. SSUS Data Package, SP-PAY-T, NASA/KSC, June 1976.
16. Transportation of Mariner Planetary Automated Spacecraft from JPL to KSC/ETR, Preliminary, JPL, February 3, 1975.
17. Payload Transportation Study, History of Transporting Spacecraft to AFETR, VW-1, JPL, July 22, 1975.
18. Viking 75 Orbiter Transportation Between Pasadena and Air Force Eastern Test Range, JPL Procedure V075 106.00A, October 3, 1974.
19. Spacelab Transportation Data Package, T. O'Neil, NASA/MSFC, August 1975.

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20. Outsized Payload Data Package, C. Mundie, NASA/MSFC, May 1975
21. A Study of Interim Transportation for Goddard Shuttle Payloads, NASA/GSFC, May 28, 1975.
22. Southern Railway Envelope Data, January 1976.
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24. Spacelab PDR Package, RP-HS-13-0001-76, NASA/MSFC (ESRO), 1976.
25. Spacelab Level III Integration Data Package, NASA/KSC, J. Dickinson, September 29, 1975.
26. Trucks and Truck Trailers, Truck Trailer Manufacturers Association, 1975.
27. Spacelab GSE Allocation and Requirements Plan, NASA/MSFC, 40A99005, February 27, 1976.
28. Payload Processing Facilities, NASA/KSC, April 1, 1974.
29. KSC Launch Site Accommodations Handbook for STS Payloads, NASA/KSC, K-SM-14, Rev. 2, June 1975.
30. Space Shuttle Program Ground Support Equipment General Design Requirements, JSC Spec. SW-E-0002B, January 6, 1976.
31. Air Transportability Requirements, MIL-A-8421F
32. DOD Engineering for Transportability, AR 70-44
33. Packaging and Handling of Dangerous Materials for Transportation by Military Aircraft, AF-71-4
34. Environmental Test Methods, MIL-STD 810C

Catalogs and Engineering Data

Environment Control

35. Shock, Nanway Division/Lear Siegler, Inc
36. Shock, Goodyear
37. Climate Control, Sundstrand Aviation
38. Shock & Acceleration, Datel Systems, Inc.
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40. Climate Control, Ellis & Watts

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Environment Control (Continued)

41. Pressure Control, Military Packaging Specialties
42. Shock, Endevco
43. Monitoring, Lockheed Electronics/Ensco, Inc.
44. Climate Control, Thermo King
45. Climate Control, Trane
46. Climate Control, Polar Stream
47. Climate Control, Carrier Transicold
48. Monitoring, Unholtz Dickie Company
49. Monitoring, Impacto Graph Company
50. Monitoring, Bendix Systems Division
51. Aircraft, Saturn Airways
52. Aircraft, World Airways
53. Aircraft, Trans International Airlines
54. Truck, Fruhauf
55. Truck, Dorsey

Cargo Handling

56. Aircraft, Brooks Y Perkins
57. Containers, Livingston Armadillo, Inc
58. Covers, Richmond Corporation
59. Covers, Langdon Corporation
60. Covers, Associated Bag
61. Communications, Motorola Corporation
62. Transporting Containers, Craig Systems
63. Transporting Containers, Gichner Mobile Systems
64. Transporters, Calcon Space Facility, Inc

APPENDIX A

PRELIMINARY USERS HANDBOOK OUTLINE

STANDARD PAYLOAD TRANSPORTATION SYSTEM - MANAGEMENT OPS

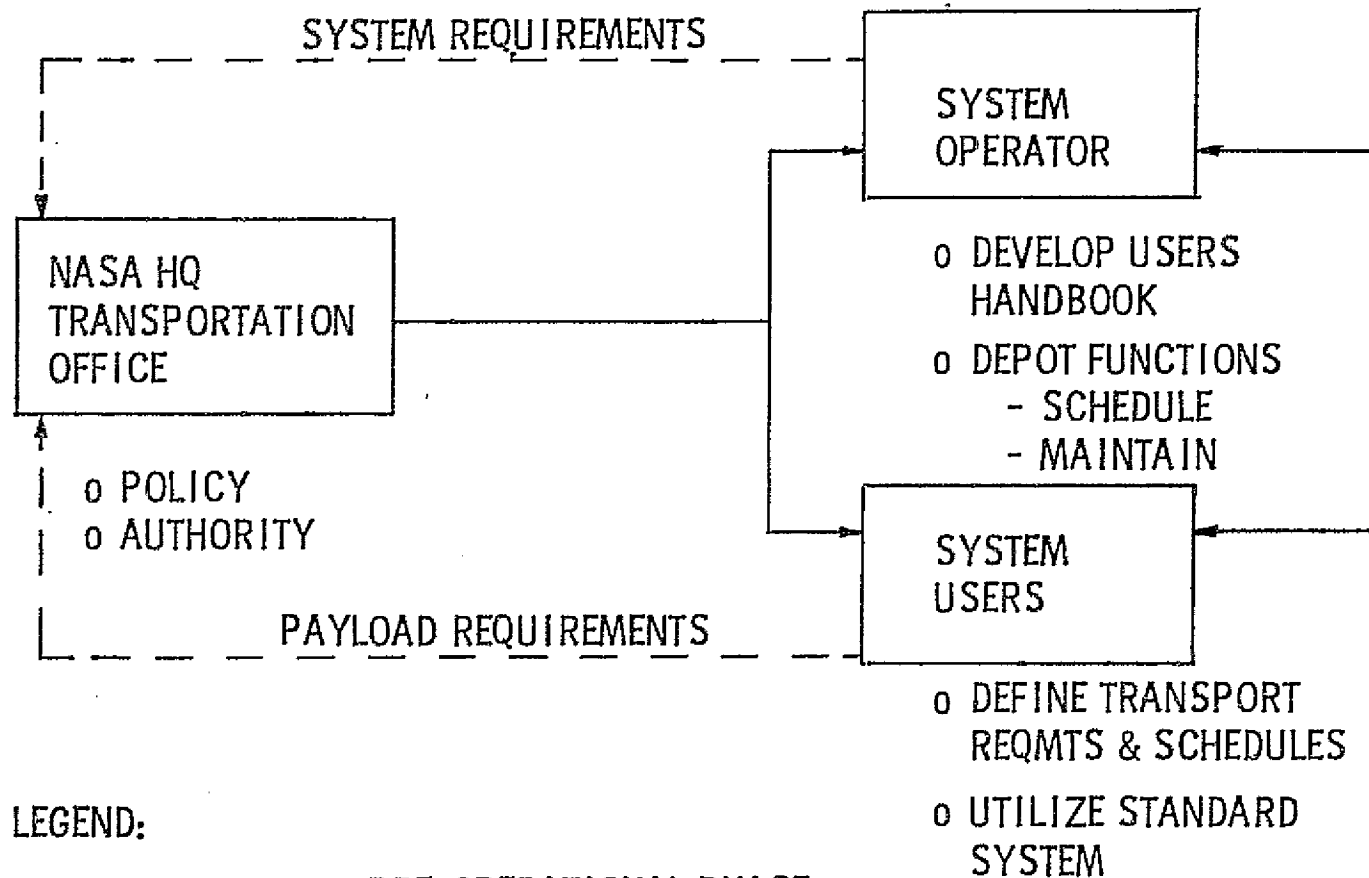
To derive the top level content of the Users Handbook, the management activities involved in the definition and use of the standard transportation system were defined. The dashed lines on the facing chart indicate the flow of information and requirements for payload transportation to the NASA Headquarters Transportation Office as a basis for defining the standard system. The management functions and interfaces involved after the transportation system is operational are shown with solid lines. The Headquarters Transportation Office is responsible for establishing overall policy and providing the authority to implement system operation.

The system operator is responsible for operating and maintaining the system and for overall scheduling activities. The operator is also responsible for developing the handbook to define for the users the capability of the system and the user responsibilities regarding support request definition and timing.

Users will submit payload shipment requirements to the system operator, coordinate mode of travel when conflicts arise and accompany their payload in transit.

A more detailed view of the operator/user interface is shown on the next chart.

STANDARD PAYLOAD TRANSPORTATION SYSTEM - MANAGEMENT OPERATIONS



LEGEND:

- — — — — PRE-OPERATIONAL PHASE
- OPERATIONAL PHASE

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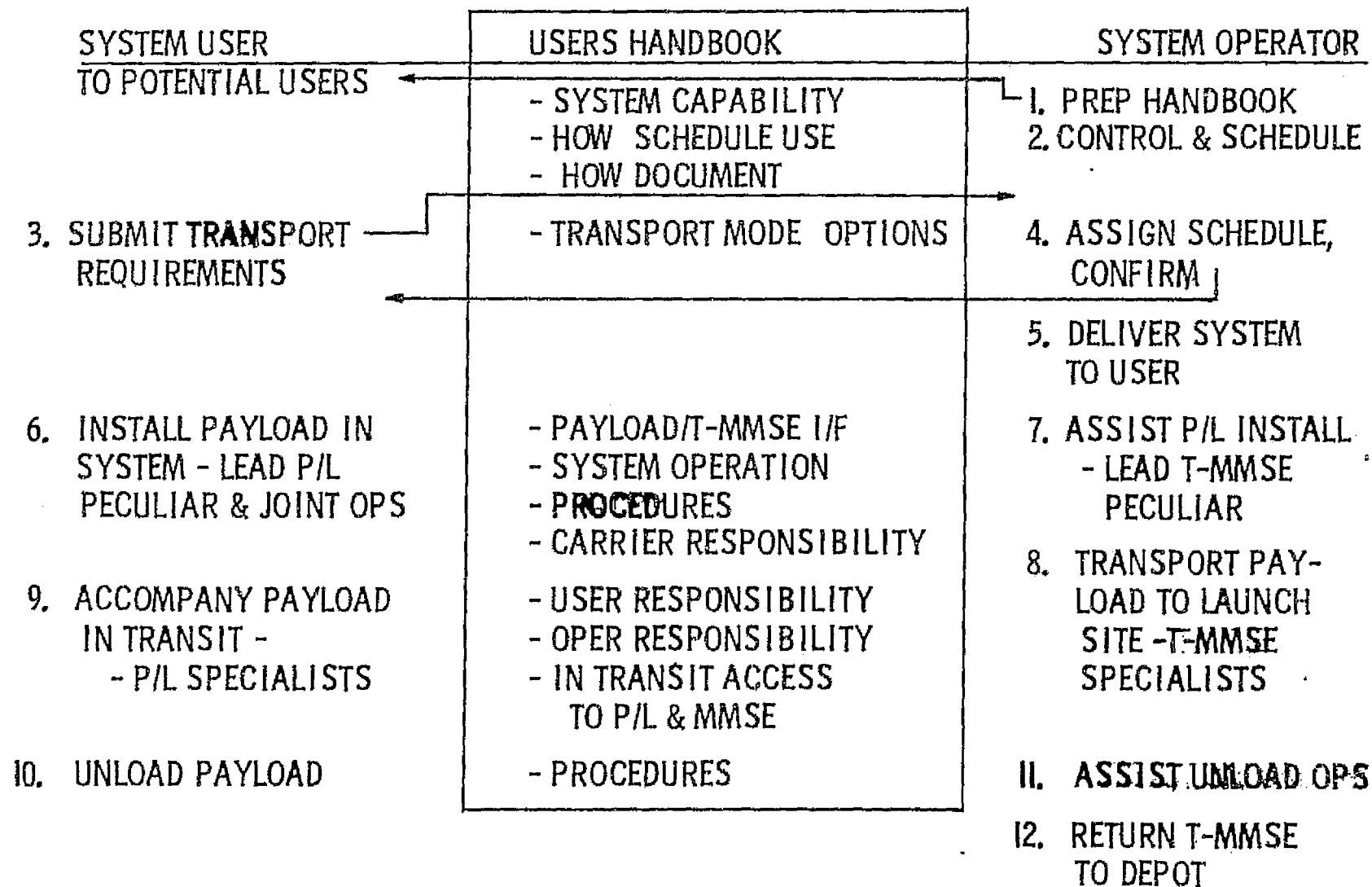
STANDARD PAYLOAD TRANSPORTATION SYSTEM - OPERATIONS SCENARIO

The interface between the system operator and users is shown on the facing page. The functions performed by the operator and users are shown on both sides of the chart and the way each function or interface is controlled by the User's Handbook is shown in the center block. The functions are numbered to indicate the typical sequence of activities.

The handbook is prepared by the operator as a means of controlling interfaces between the transportation system and the payload and to advise potential users of system capability and operations: the user must initiate the transport cycle by advising the operator of payload shipping requirements and schedule. The operator responds to user requests with a schedule confirmation and provides the system at the Level IV Site as required.

The activities involved in loading, shipping and unloading the payload are shared by the operator and user as indicated. The type of data required by a user to accomplish each step is as listed. The data list essentially provides an outline of the content of the User's Handbook. The handbook outline is provided on the next chart.

STANDARD PAYLOAD TRANSPORTATION SYSTEM - OPS SCENARIO



STANDARD PAYLOAD TRANSPORTATION SYSTEM - USERS HANDBOOK

The facing chart lists seven broad categories of data which should be incorporated in a Users Handbook on the transportation system. Each of the categories is discussed in more detail on the next seven charts.

This data was derived by considering the functions that must be performed by the system operator and users and the type of data required to perform the functions in the operations scenario discussed on the previous chart. The data was grouped as shown to serve as a basic outline for the Users Handbook.

STANDARD PAYLOAD TRANSPORTATION SYSTEM - USERS HANDBOOK

GENERAL

- o INTRODUCTION
- o UTILIZATION POLICY & AUTHORITY

MANAGEMENT OPERATIONS

- o ORGANIZATION
- o RESPONSIBILITIES
 - OPERATOR
 - USER
 - CARRIER
- o FUNCTIONAL INTERFACES
 - TRANSPORT SYSTEM
 - LAUNCH SITE PAYLOAD OPERATIONS

SYSTEM DEFINITION

- o OPERATIONS CONCEPT
 - BASELINE
 - CONTINGENCY
- o SYSTEM CAPABILITY
 - CONFIGURATION
 - CAPACITY
- o CARRIER DEFINITION

SYSTEM OPERATIONS

- o BASELINE
 - LOAD/UNLOAD
 - IN TRANSIT
- o CONTINGENCY

SYSTEM INTERFACES

- o PAYLOAD TO SYSTEM
- o SYSTEM TO SYSTEM
- o SYSTEM TO FACILITIES

DOCUMENTATION

- o OPERATOR
- o USER

USE RESTRICTIONS

- o SPACELAB
- o AUTOMATED
- o IUS/SSUS/TUG

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THE PAYLOAD TRANSPORTATION USERS HANDBOOK OUTLINE

The seven groups of data required by the system users are listed on the facing chart, each as a chapter of the handbook. Details of the type data required in each chapter is shown on succeeding charts.

THE PAYLOAD TRANSPORTATION USERS HANDBOOK OUTLINE

PREFACE

CHAPTER 1: BASIC PRINCIPLES

CHAPTER 2: SYSTEMS DESCRIPTION

CHAPTER 3: SYSTEMS OPERATIONS

CHAPTER 4: CONTINGENCY SYSTEMS

CHAPTER 5: MANAGEMENT OPERATIONS

CHAPTER 6: PAYLOAD - T-MMSE INTERFACES

CHAPTER 7: DOCUMENTATION

APPENDICES

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USERS HANDBOOK - BASIC PRINCIPLES

This chapter should define the scope of the handbook and its relevance to payload transportation, list applicable documents (only those specifically required, as the handbook should stand alone to the maximum degree possible), define the overall NASA policy and authority relative to system use and specify procedures for processing deviations to the policy or waivers in special cases.

USERS HANDBOOK - BASIC PRINCIPLES

100 - SCOPE

101 - APPLICABLE DOCUMENTS

102 - DEVIATION AND WAIVER REQUESTS

103 - POLICY

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USERS HANDBOOK - SYSTEMS DESCRIPTION

The major items of information on transportation system definition required by the user include a description of the baseline system and the capabilities of the system and carrier hardware.

The capability of the small and large systems must be defined for the users. The configuration and payload capacity of both systems must be defined and a description of typical payload accommodations would be valuable to the user in planning transportation activities. The user must also be appraised of loads which payloads could encounter in both systems using the various payload adapter configurations.

USERS HANDBOOK - SYSTEMS DESCRIPTION

200 - BASELINE SYSTEM

205 - LARGE UNIT

201 - SMALL UNIT

206 - CONFIGURATION

202 - CONFIGURATION

207 - LOAD CAPABILITY

203 - LOAD CAPABILITY

208 - ENVIRONMENT CONTROL AND
MONITORING SYSTEM

204 - ENVIRONMENTAL CONTROL
AND MONITORING SYSTEM

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USERS HANDBOOK - SYSTEMS OPERATIONS

This section must define in detail the total operations aspects of the system. The function of the Transportation Control Center must be defined including data such as T-MMSE Inventory Control, Shipping Requirements and Forecasts and the Integrated Scheduling activities.

The systems operations section should define procedures for using, interfacing with and operating the transportation system. The normal procedures for typical activities (load payload, unload, TEMS hookup and operation, etc.) must be defined.

USERS HANDBOOK - SYSTEMS OPERATIONS

300 - PAYLOAD TRANSPORTATION CONTROL CENTER FUNCTION

301 - INVENTORY CONTROL OF T-MMSE

302 - SHIPPING REQUIREMENTS AND FORECASTS

303 - INTEGRATED SCHEDULING

304 - BASELINE OPERATIONS

305 - PRE-SHIPMENT INSPECTION AND CERTIFICATION

306 - LOADING PROCEDURES

307 - IN-TRANSIT SERVICES

- TECHNICIAN ESCORTS
- P/L MONITORING
- IN-ROUTE REPORTING SYSTEMS
- INCIDENT/ACCIDENT NOTIFICATION
- CORRECTIVE ACTION

308 - UNLOADING PROCEDURE

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USERS HANDBOOK - CONTINGENCY SYSTEMS

This section should define the top level procedures for using aircraft on a contingency basis for payload transportation. This data should inform the user of those differences in operating procedures which could impact the payload or support equipment design.

In addition to aircraft transport, the section should define other available modes of transport such as barge.

USERS HANDBOOK - CONTINGENCY SYSTEMS

400 - GENERAL

401 - SPECIAL MISSION AIRLIFTS

402 - AIR FORCE AIRLIFT CAPABILITY

403 - COMMERCIAL AIR CARGO AVAILABILITY

404 - OTHER AVAILABLE TRANSPORT MODES

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USERS HANDBOOK - MANAGEMENT OPERATIONS

The operating organization must be defined so the user can determine his points of access in using the system. The responsibilities of each major participant in intersite transportation, including the operator (transportation system manager), user, and carrier, must be apprised of their responsibilities as well as those of the other organizations.

The organizational interfaces must be defined to a level of detail consistent with the users need for information. For example, if the system operator is responsible for contracting carrier services, the user must be aware of this and also be assured that the carrier vehicle delivered to transport his payload will meet the payload requirements relative to temperature, relative humidity, shock, etc.

Another interface which must be defined is that between the payload transportation organization and other organizations involved with various facets of payload operations. For example, a launch site payload organization exists to facilitate payload processing at the launch site. If KSC is assigned the role of payload transportation system operator, the operational interfaces between this organization and the payload operations group must be defined and organized to aid the user in defining the full range of requirements relating to both transportation and launch processing of his payload.

USERS HANDBOOK - MANAGEMENT OPERATIONS

500 - RESPONSIBILITIES

501 - TRANSPORTATION SYSTEM
MANAGER

502 - PAYLOAD MANAGER

503 - COMMERCIAL TRANSPORTATION
CARRIER

504 - FUNDING POLICY

505 - TRANSPORTATION SERVICE
DEFICIENCIES

506 - T-MMSE CONFIGURATION CONTROL

507 - CARRIER SELECTION

508 - CARRIER CERTIFICATION

509 - IN-TRANSIT PERSONNEL
RESPONSIBILITIES

- TECHNICIAN ESCORTS

- CARRIER PERSONNEL

510 - STATE HIGHWAY REQUIREMENTS

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USERS HANDBOOK - SYSTEM INTERFACES

This section should define the direct payload to transportation system interfaces in detail and also define the interfaces which indirectly impact the payload, such as the system to system interfaces and those between the system hardware and facilities.

The interfaces between the system and the payload which must be defined include mechanical/structural, electrical, instrumentation and data, and environmental interfaces. The system to system interfaces define how the various system elements mate and operate as a total system. The system to facility interfaces should include top level definition (airlock size, crane capacity, cleanliness levels, power availability, etc.) of launch site facilities and the capability of the carrier and transportation system hardware to interface with the facilities. This section should include data to enable the user to assess the applicability and compatibility of the transportation system with facilities at his center.

Applicable drawings, procedures and instructions relating to the interfaces must also be defined.

600 - MECHANICAL

601 - FUNCTIONAL

602 - DRAWINGS

603 - PROCEDURES

604 - INSTRUCTIONS

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USER HANDBOOK - DOCUMENTATION

This section should define the documentation required in the operation and use of the transportation system. The definition should include any required format for the documentation required by the system user to define the payload transportation requirements and should include the applicable submit-tal schedule.

The handbook must also define for the user the documentation he would receive from the system operator in response to his request for transportation and to confirm the shipping schedule.

Examples of the type data which could be included in the appendices are as shown below.

DOCUMENTATION - TBD

APPENDICES

- POINTS OF CONTACT
- DEFINITIONS
- APPLICABLE REFERENCES
- REGULATIONS AND DOCUMENTS

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APPENDIX B

TRANSPORTATION SYSTEM INTERFACE DEFINITION

TRANSPORTATION SYSTEM INTERFACE DEFINITION

The purpose of this task is to define the interfaces between payloads and the intersite transportation system. The direct payload-to-system interfaces are addressed as well as the interfaces between various system components (e.g., container platform to carrier).

The interfaces, although overlapping in some areas, are grouped into four general areas - mechanical, electrical, instrumentation and data, and environmental. Generally each interface applies to both the small and large systems. The electrical interface is an exception in that electrical power for the small system is supplied by the carrier (van) and the large system is supplied by a separate Auxiliary Power Unit.

A more detailed listing of interfaces is provided on the following charts.

TRANSPORTATION SYSTEM INTERFACE DEFINITION

SCOPE

DEFINE PAYLOAD TO TRANSPORTATION SYSTEM INTERFACES

MECHANICAL

- PAYLOAD ENVELOPE
- PAYLOAD TO ADAPTER(S)
- ADAPTER TO PLATFORM
- PLATFORM TO CARRIER

ELECTRICAL

- PAYLOAD TO CARRIER
(SMALL)
- PAYLOAD TO APU
(LARGE)

INSTRUMENTATION & DATA

- TEMP., RELATIVE HUMIDITY
- SHOCK, VIBRATION
- ELECTRICAL POWER
- ALARM

ENVIRONMENTAL

- CLEANLINESS
- TEMPERATURE
- RELATIVE HUMIDITY

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PAYLOAD/TRANSPORTATION SYSTEM INTERFACES

The type of interfaces involved in each group are listed on the following four charts. Various payload adapters are required to accommodate the wide range of automated and Spacelab payloads. Regardless of the configuration the adapters provide structural attachment of the payload to the system and also shock isolate the payload from the system.

Electrical power is provided by the van for the small system and by the APU/ECS unit for the large system. Both systems provide 28 VDC to the payload, as required.

Environmental interfaces are restricted in this system to those which provide physical protection for the payload and which control the temperature and relative humidity within the system.

The instrumentation and data interfaces include the sensors involved in measuring shock/vibration, temperature, relative humidity, power to the payload and TEMS, the recording capability required for each and the alarm system which indicates out of tolerance conditions.

Details of the various system interfaces are provided on the following charts.

PAYLOAD/TRANSPORTATION SYSTEM INTERFACES

PAYLOAD INTERFACE	SMALL SYSTEM	LARGE SYSTEM
MECHANICAL/STRUCTURAL	PAYLOAD ADAPTER - STRUCTURAL MOUNT - SHOCK ISOLATION CARRIER AIR RIDE SYSTEM - SHOCK ISOLATION	PAYLOAD ADAPTER - STRUCTURAL MOUNT - SHOCK ISOLATION CARRIER AIR RIDE SYSTEM - SHOCK ISOLATION
ELECTRICAL	CARRIER POWER - 28 VDC	AUXILIARY POWER UNIT - 28 VDC - 115 VAC, 50/60 HZ
ENVIRONMENTAL	CARRIER CLIMATE CONTROL UNIT - TEMP & RH STATIC FREE BAG - CLEANLINESS AIR RIDE VAN - PROTECTION	ENVIRONMENTAL CONTROL UNIT - TEMP & RH STATIC FREE BAG - CLEANLINESS HARD CONTAINER - PROTECTION
INSTRUMENTATION/ DATA	ACCELEROMETERS TEMPERATURE RELATIVE HUMIDITY POWER ALARM SYSTEM	ACCELEROMETERS TEMPERATURE RELATIVE HUMIDITY POWER ALARM SYSTEM

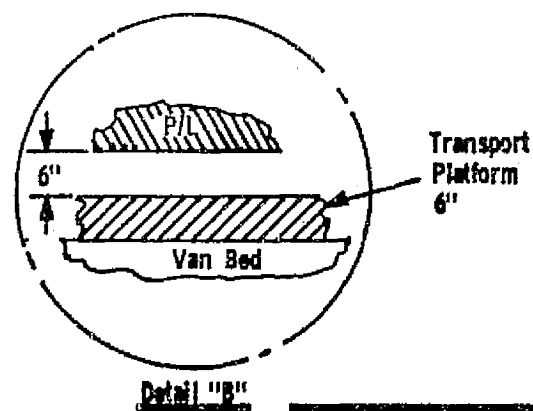
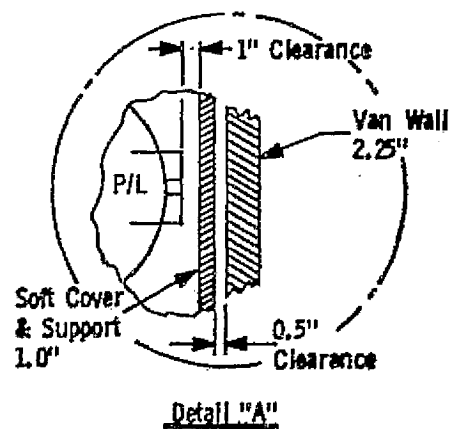
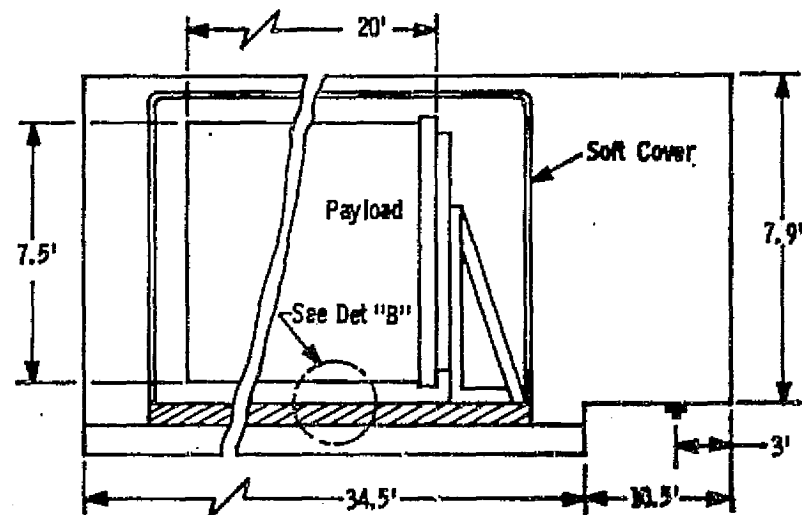
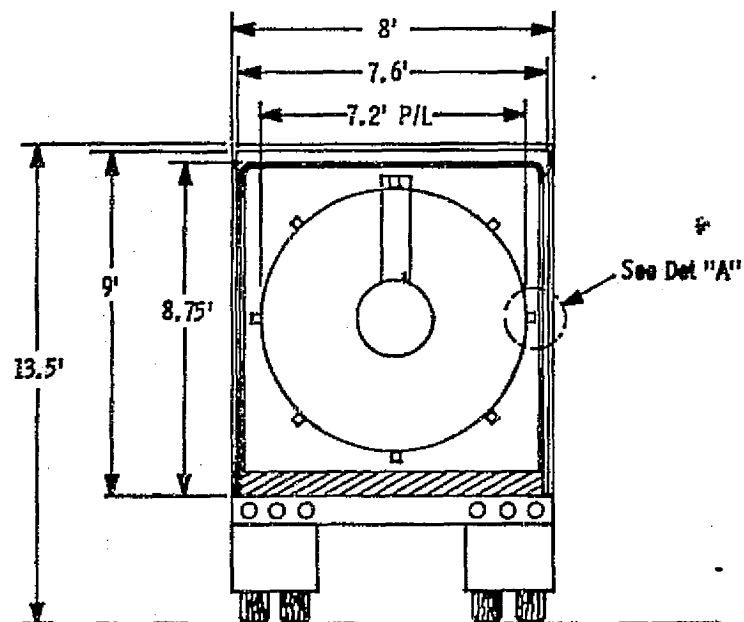
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PAYLOAD EVELOPE - SMALL SYSTEM

The facing chart shows a typical 7.2 ft diameter payload installed in a standard air-ride van. The length of the lower section of the van (exclusive of the goose neck) is 34.5 ft (assuming an overall van length of 45 ft).

The maximum payload size accommodated in the van is 7.2 ft wide x 7.5 ft high by approximately 20 ft long. The determining factors of the maximum payload length are the space requirements of the final design of the payload adapters and container tie-down system. The side clearance is critical in the small system with the maximum allowable payload (7.2 ft) installed. The soft cover support structure is assumed to be constructed of 1 inch tubular stock and the cover itself is 1 inch thick. If the final design of the payload adapter requires that the adapter spokes extend substantially beyond the payload diameter, the adapter could be clocked to reduce the potential interference with the cover and support.

The clearance below the payload is 6 inches. The adapter structure is 4 inches thick and an additional 2 inches is allowed for payload clearance. With a payload 7.5 ft high, the clearance above the payload is 2 inches to the cover and 2 inches between the cover and van ceiling.



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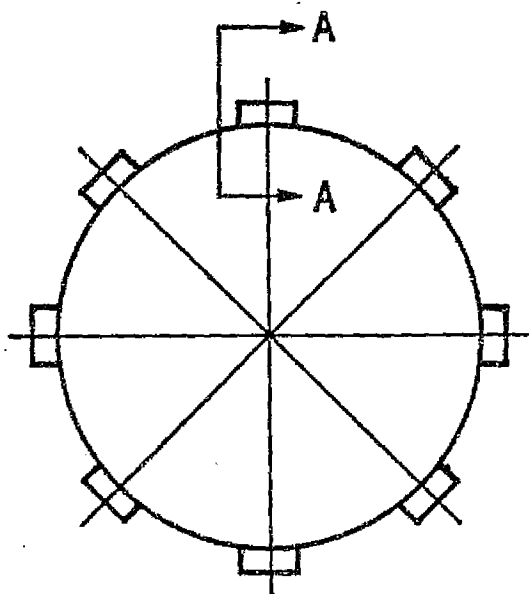
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PAYLOAD/ADAPTER INTERFACE - END MOUNT

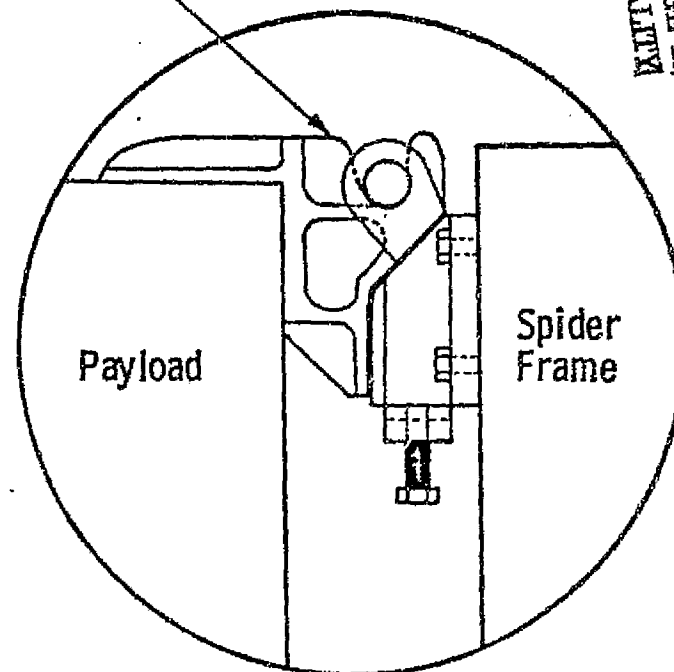
The end mounted payload adapter interface is designed to be compatible with the standard payload flight interface defined as part of the flight MMSE study (NAS8-31615 performed by Martin Marietta for MSFC). Eight interface points are located on the payloads (or the flight MMSE payload interface adapter attached to the payload) as depicted in the facing chart. The transport system adapter has eight arms, or spokes, on which the latch assemblies are located to mate with the payload interface. The latch assemblies slide on the adapter spokes to accommodate various payload diameters.

The active half of the latch assembly is on the adapter and is manually operated. The latch is drawn tight against the payload interface hook by turning the screw fitting until the bearing surfaces of the hook and latch are mated. The double adjustment feature (sliding latch assembly and screw) ensures flexibility and a secure attachment at each interface point.

PAYLOAD / ADAPTER INTERFACE - END MOUNT



Latch Ear Outboard



View "A-A"

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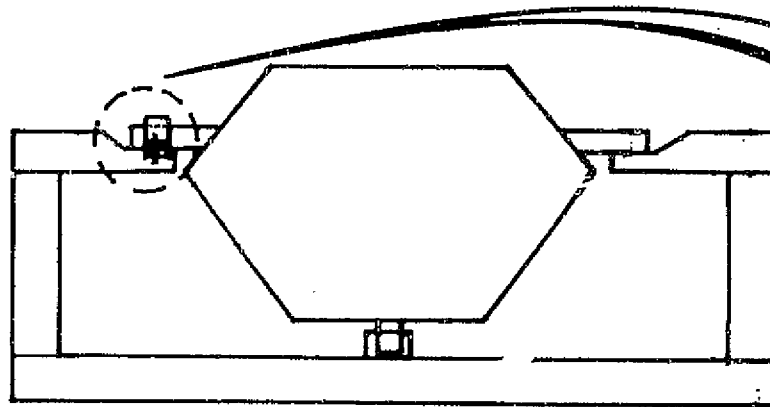
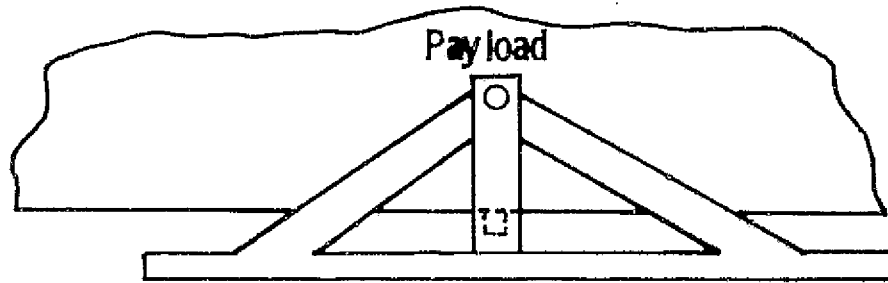
PAYLOAD/ADAPTER INTERFACE - CENTER MOUNT

The center mount payload adapter is for use specifically with the GSFC Multi-mission Modular Spacecraft (MMS) system. The adapter mates with the three spacecraft trunnion pins located near the spacecraft center of gravity.

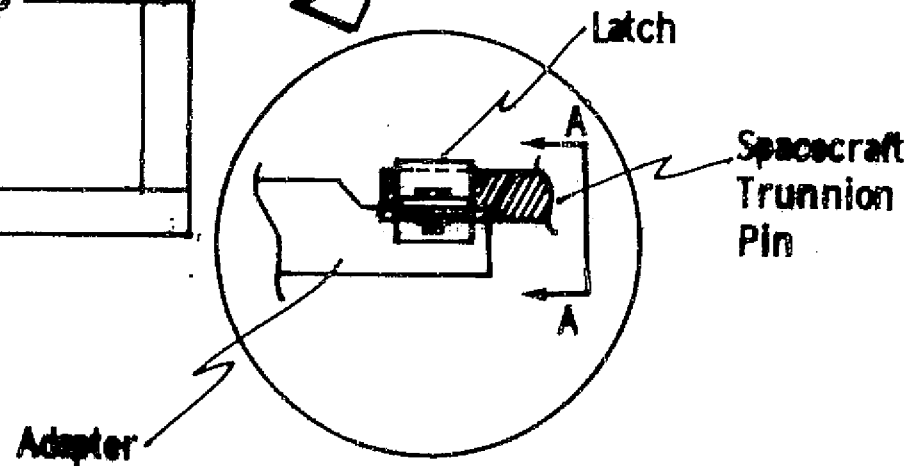
The payload is transported in the same position in which it will be in the orbiter payload bay with the Shuttle in the horizontal position.

The three trunnion pins mate with the adapter and are held in place with mechanical latches. Most of the spacecraft weight is supported on the two top trunnions by the adapter arms and the third trunnion prevents spacecraft rotation.

PAYLOAD/ADAPTER INTERFACE - CENTER MOUNT



View A - A



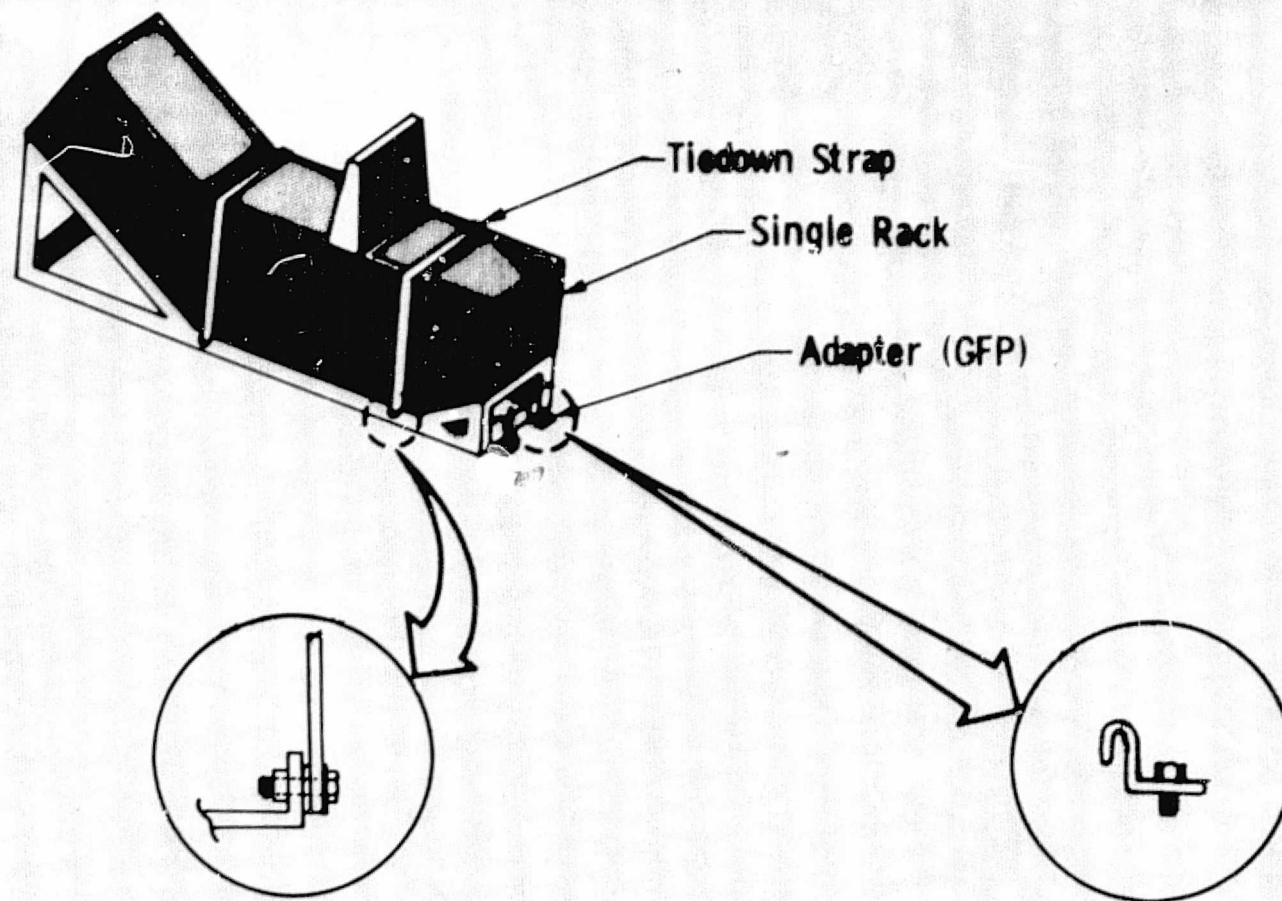
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PAYLOAD/ADAPTER INTERFACE - SPACELAB RACK

The adapter for the Spacelab racks (singles or doubles) is existing Spacelab provided hardware and is shown for reference only. The adapter is normally used in conjunction with a special base and cover which would not be required when used to ship racks in the small intersite transportation system.

The tie-down clips, shown in the detail on the facing page, may be required if the presently undefined design of the adapter tie-down system is not compatible with the intersite transport platform.

PAYLOAD/ADAPTER INTERFACE - SPACELAB RACK (GFP)



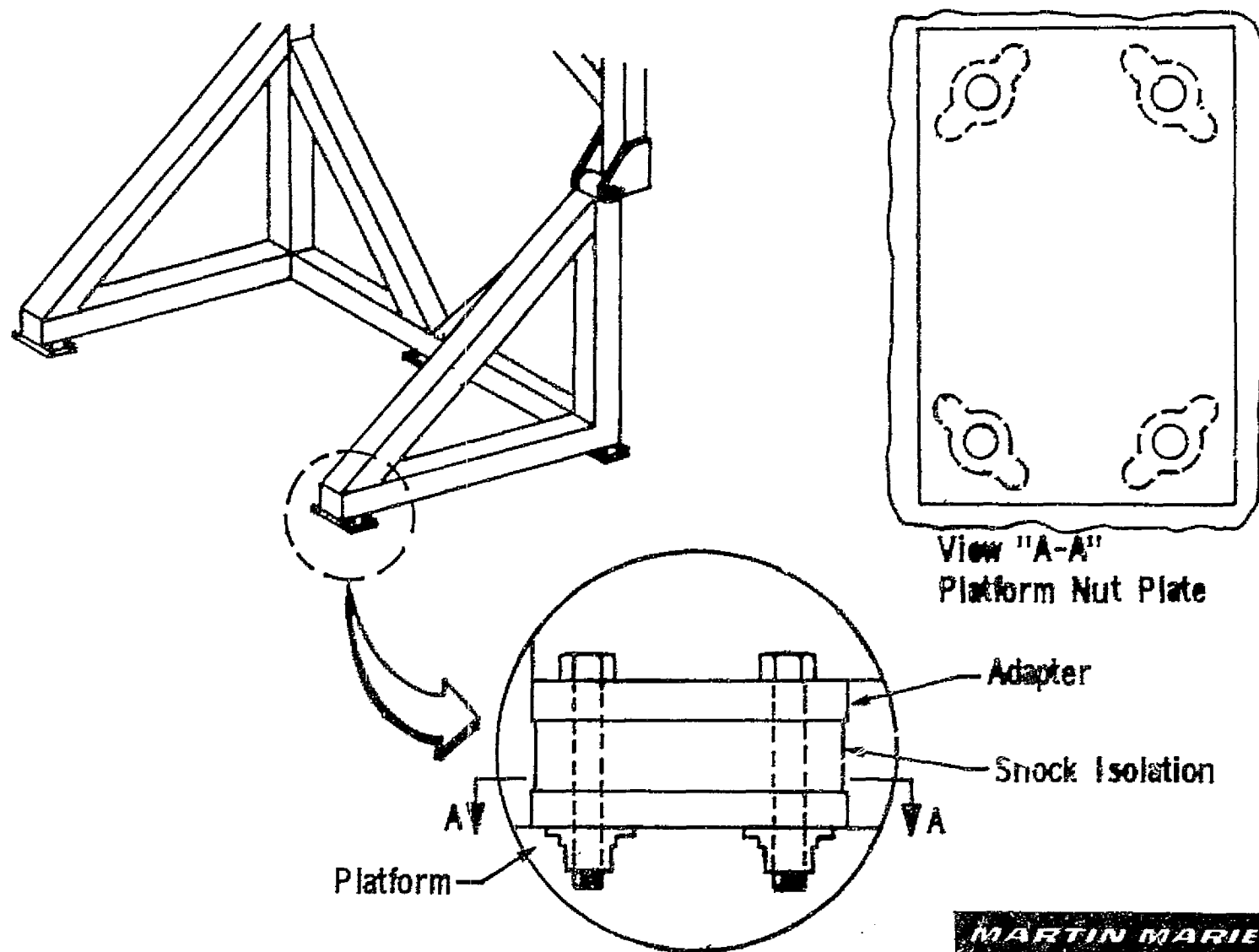
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PAYLOAD ADAPTER/TRANSPORT PLATFORM INTERFACE

The interface between payload adapters and the transport platform is shown on the facing chart. The detail is typical for the adapters used in both the small and large transport systems.

Bolt pads are provided on the base of the adapter to match the replaceable nut plates mounted in the transport platform. Shock dampening material is used between the adapter pads and the platform to reduce shock and vibration.

PAYLOAD ADAPTER/TRANSPORTER PLATFORM INTERFACE



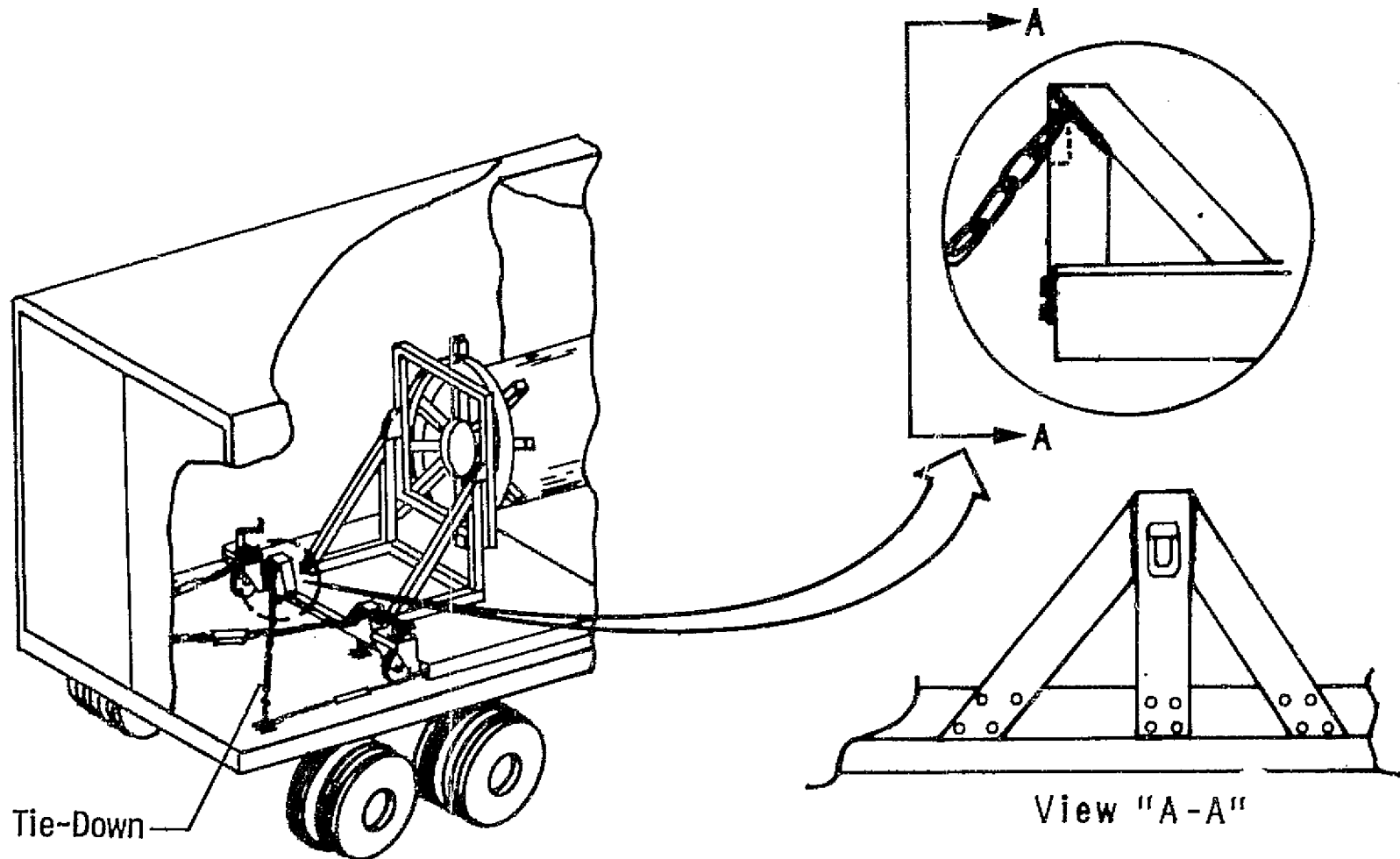
PLATFORM/CARRIER INTERFACE - SMALL SYSTEM

The standard system provided to tie the transport platform to the van consists of hook, chain, and turnbuckle assemblies of various lengths. The tie-down assemblies are used, as shown in the typical view of the facing chart, to secure the platform to the van and prevent movement within the van.

The tie-down assemblies attach to the brackets on the platform (detail on chart) and the floor ties in the van. The different length assemblies allow flexibility in the use of the standard van floor ties.

Excess chain will be padded and taped to reduce noise to the instrumentation system during movement.

PLATFORM / CARRIER INTERFACE - SMALL SYSTEM



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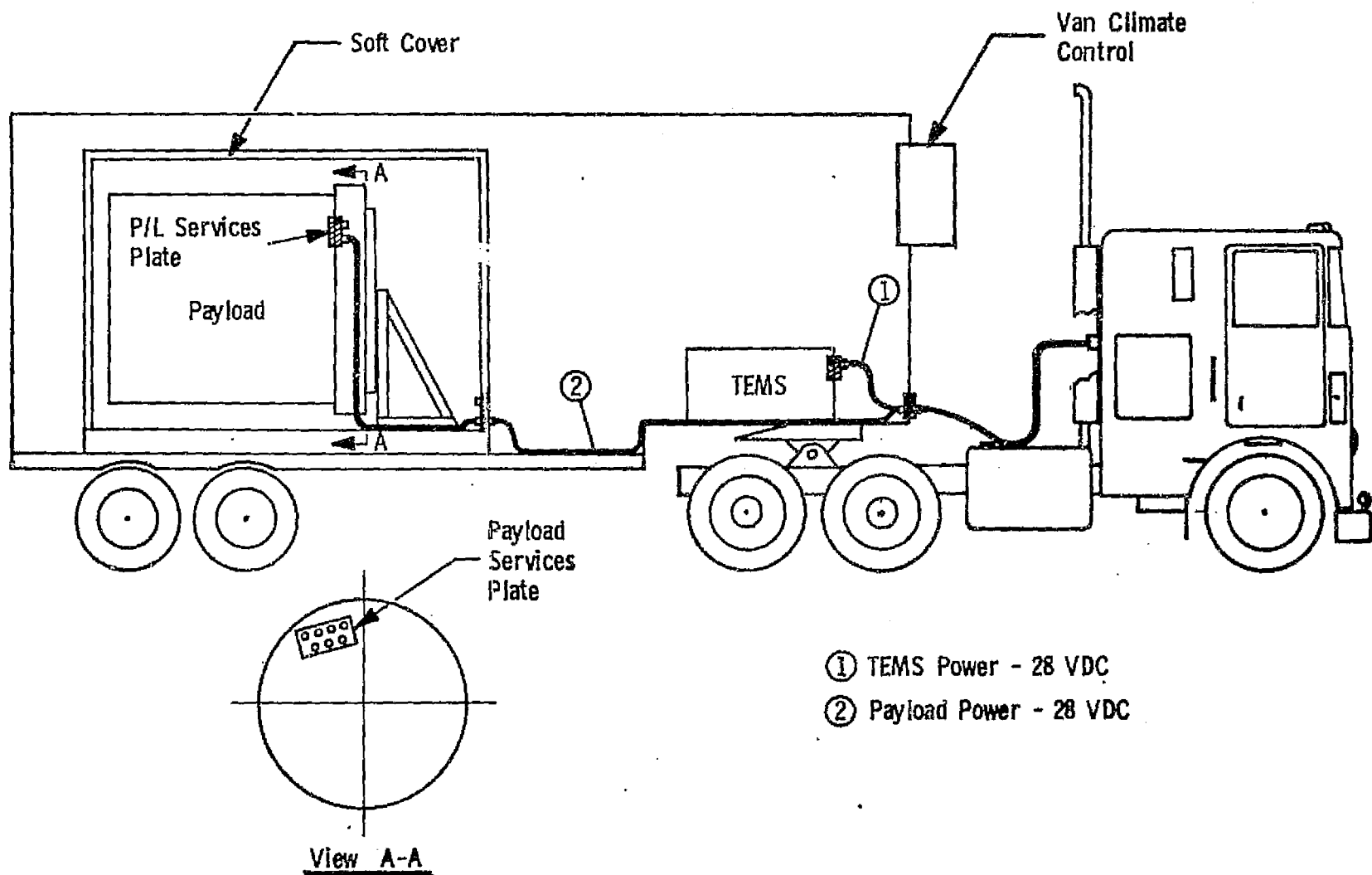
ELECTRICAL INTERFACE - SMALL SYSTEM

Electrical power required for the payloads and instrumentation (TEMS) in the small system is provided by the carrier. Interface panels are provided in the front of the standard van, through the soft cover and on the payload adapter. The payload services plate on end mounted payloads (facing chart) is a part of the standard payload interface as discussed previously regarding the mechanical payload to adapter interface.

The interface through the soft cover will be provided on a plate mounted on the transport platform. The interface panel of TEMS will carry electrical power through the unit case and subsequently to the sensors discussed on the next chart.

The electrical power provided by the tractor/van is limited to 28 VDC.

ELECTRICAL INTERFACE - SMALL SYSTEM



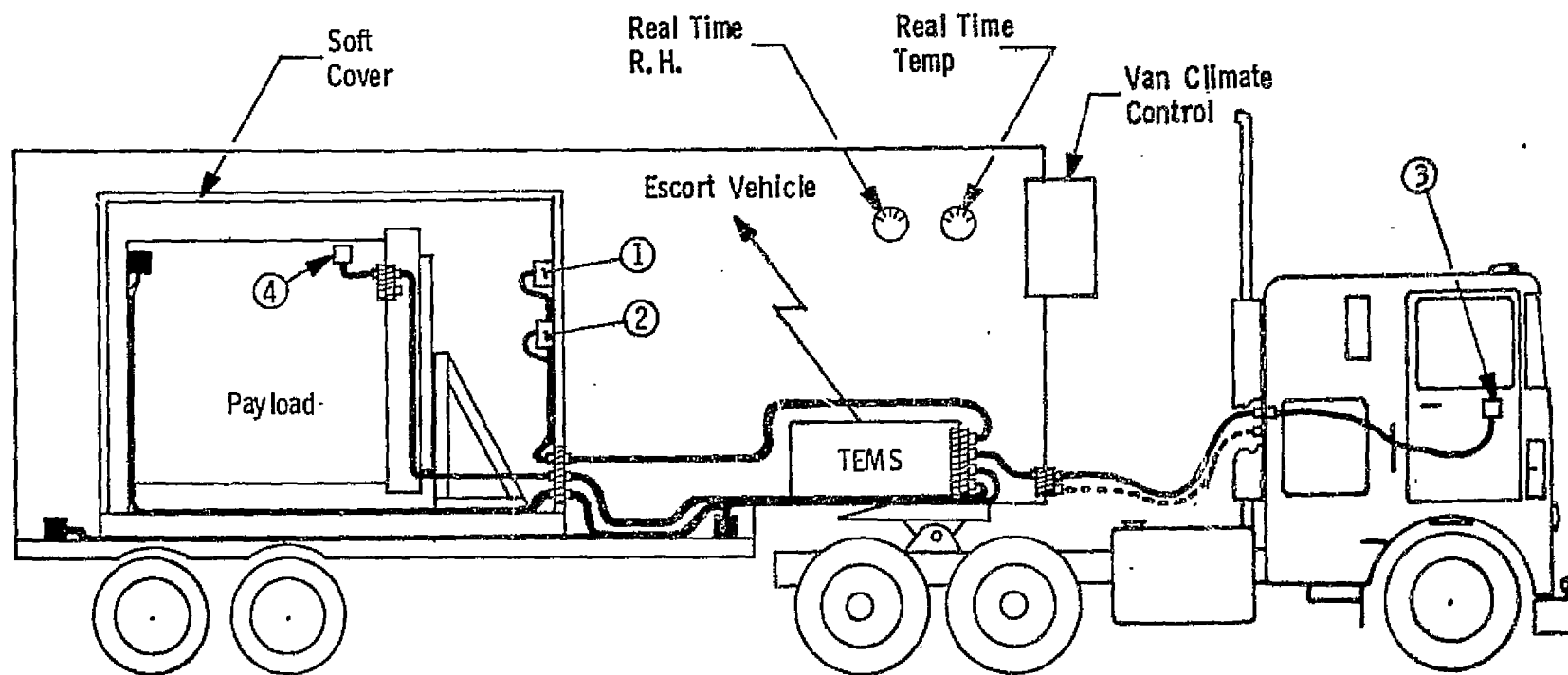
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INSTRUMENTATION AND DATA INTERFACE - SMALL SYSTEM

The instrumentation and data interfaces are depicted schematically on the facing chart. The cables interface through the same panels as the electrical system, discussed on the previous sheets (i.e., van wall, soft cover, payload and TEMS).

The TEMS sensors are as listed on the chart. The accelerometer packages (three accelerometers per package mounted triaxially) are mounted to the payload (one set) and the carrier (two sets). The temperature and relative humidity sensors are mounted on the soft cover wall. The TEMS provides an alarm system (visually and audible) which indicates out of tolerance shock, temperature and relative humidity indications as well as loss of payload or TEMS power. The alarm system indicates in both the tractor and escort vehicle.

Temperature and relative humidity indicators are mounted on the van interior wall to provide real time data.



■ Accelerometers (3 Each Triaxially Mounted, 3 Locations)

- ① Temperature Sensor
- ② Relative Humidity Sensor
- ③ Alarm Indicator
- ④ Payload Power Sensor

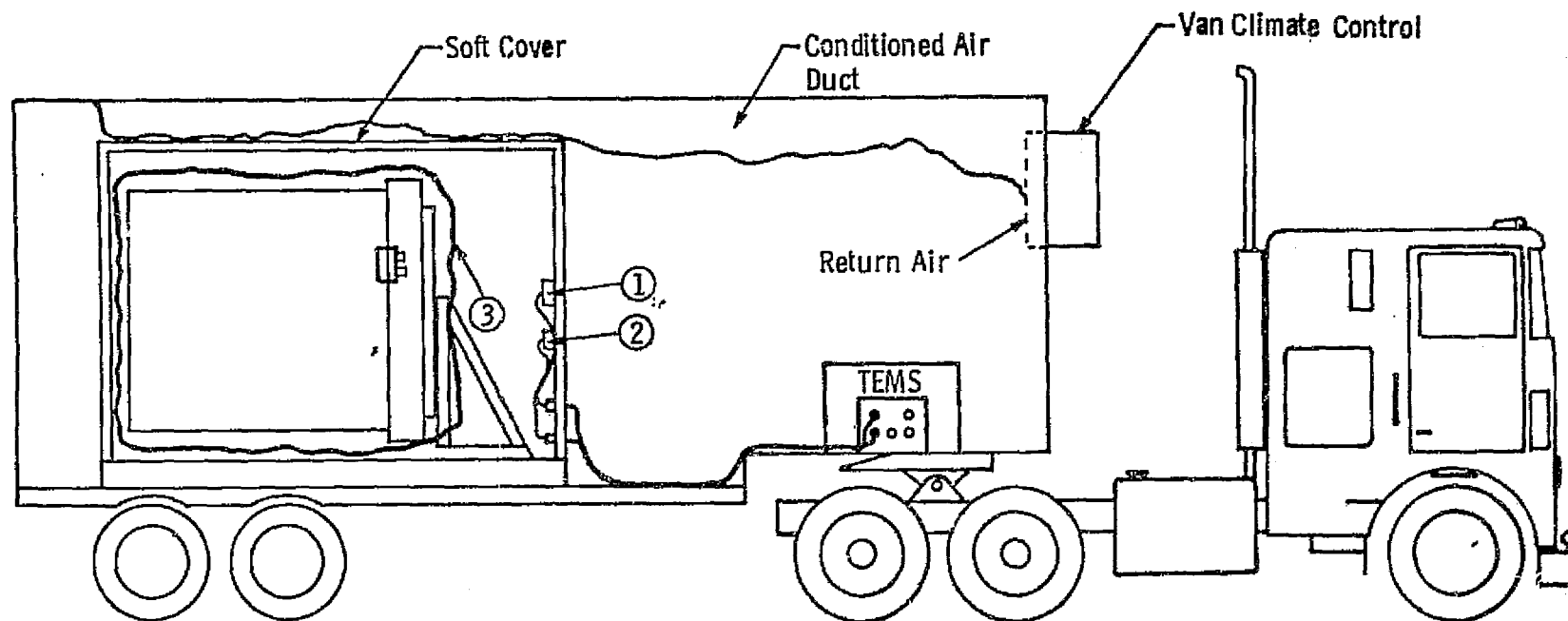
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ENVIRONMENTAL INTERFACE - SMALL SYSTEM

Environmental control (temperature and relative humidity) is provided in the small system by the van climate control system. Conditioned air is distributed through the soft duct to the exterior of the soft cover. The payload is maintained in a clean condition by the static free bag which is installed prior to installing the payload in the system.

Environmental and physical protection is provided the payload by both the van and the soft cover. The soft cover provides temporary environmental protection during van loading/unloading operations and also protects the payload during transit from other items being transported inside the van.

ENVIRONMENTAL INTERFACE - SMALL SYSTEM



- ① Temperature Monitor
- ② Relative Humidity Monitor
- ③ Anti-Static Plastic Bag To Control Payload Cleanliness

Capacity
Climate Control 19.5K BTU
3.5 Kw

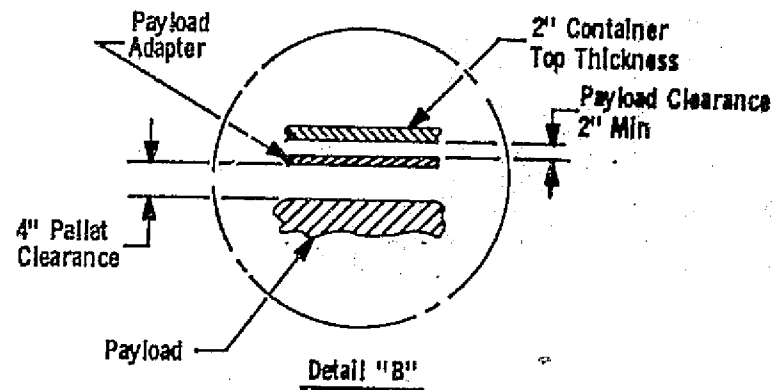
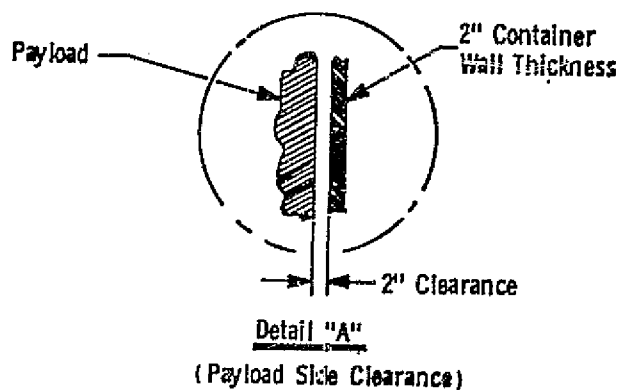
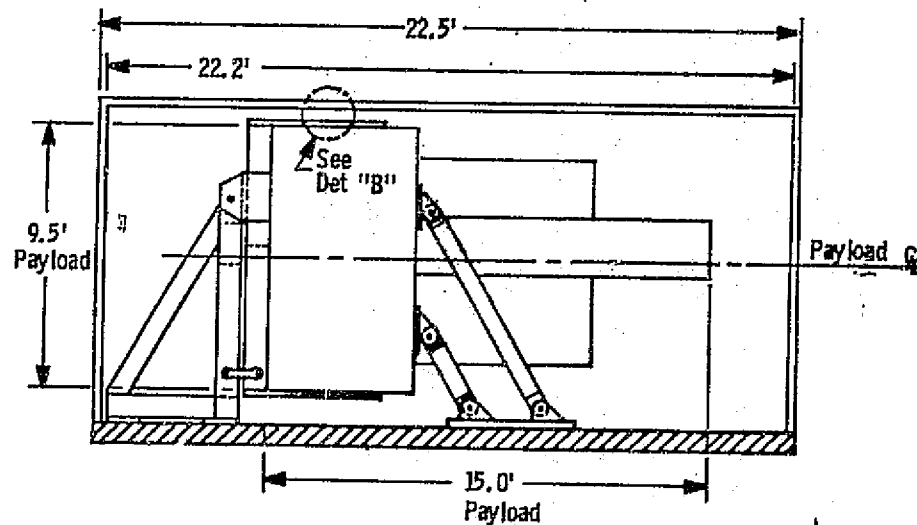
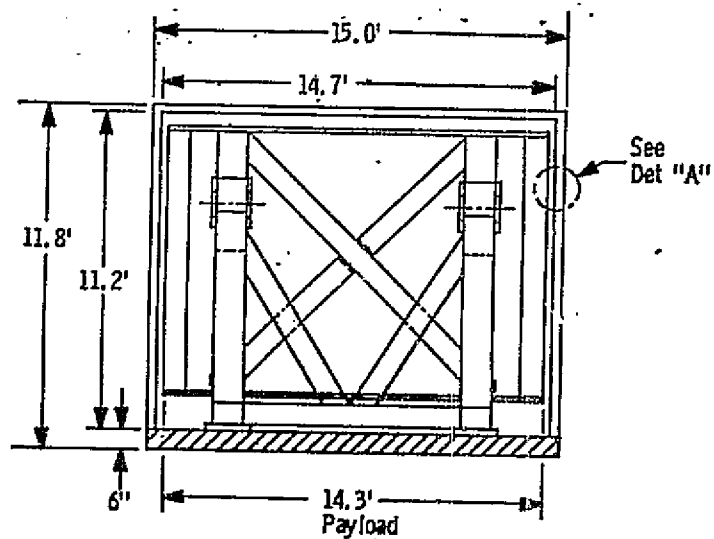
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PAYLOAD ENVELOPE - LARGE SYSTEM

The large transportation system will accommodate payloads 14'4" wide x 10'10" high x approximately 21'10" long with a minimum 2 inch clearance on all sides of the payload.

The payload will be shock isolated by means of damping material between the adapter rotation base and the container platform surface and between the "sill" forward support base and the container platform surface.

The payload depicted in the facing chart is a single Spacelab pallet which is rotated to the horizontal position. With this payload, 2 inch clearance is provided on each side, 6 inches on the bottom and approximately 12 inches on top.



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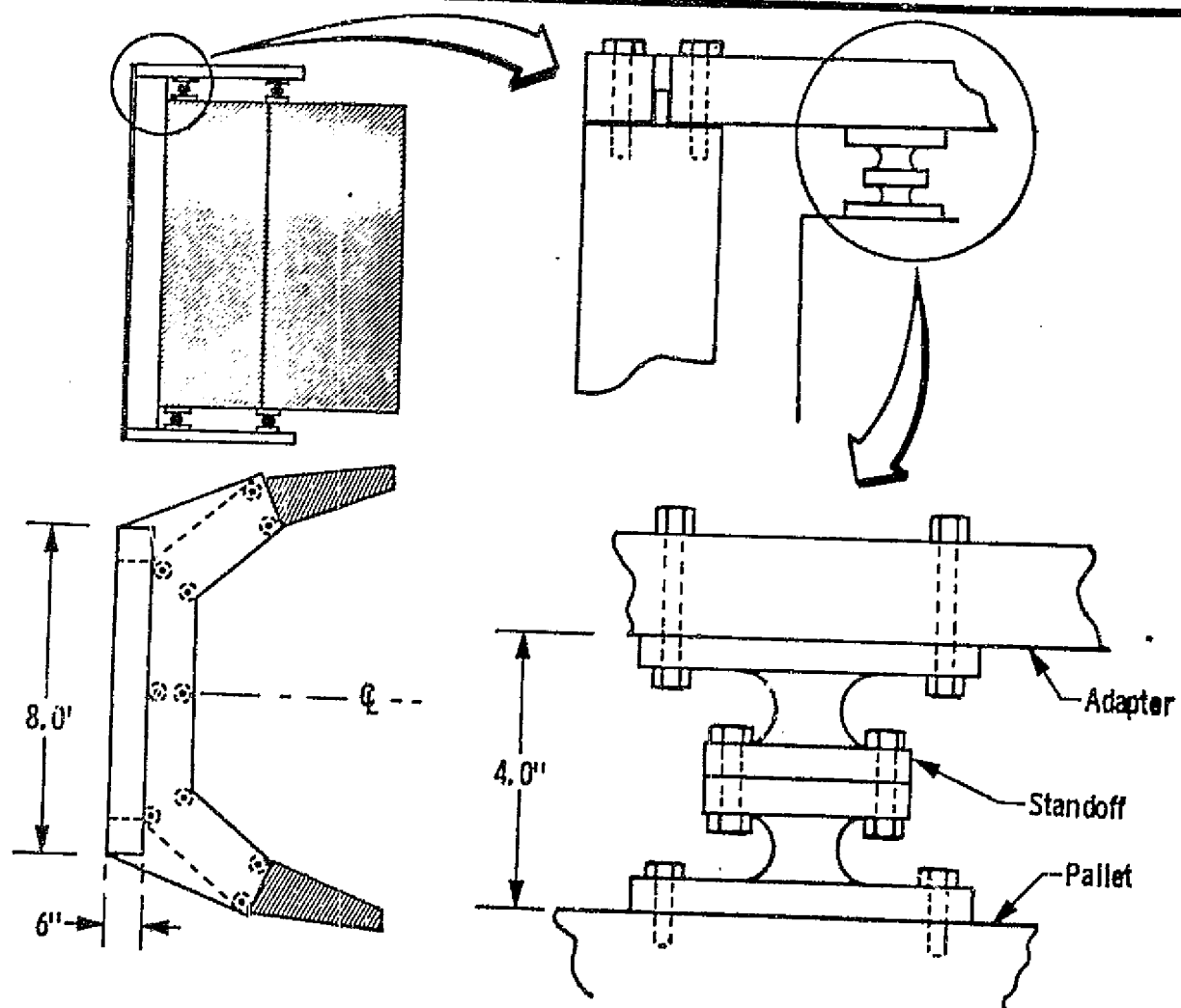
PAYLOAD PALLET ADAPTER INTERFACE (HORIZONTAL) - LARGE SYSTEM

The horizontal pallet adapter frame is of welded steel construction while the end plates are tool steel and mechanically attached to the box beam frame. The frame box beams will have plates welded on the ends. The box frame will be machined to dimensional requirements. The adapter end plate will be positioned and drilled, bolted and pinned to maintain alignment.

Back-to-back standoffs (Detail B, facing chart) similar to the ones used to attach two or more pallets together will be used to interface the pallet to the adapter. Ten standoffs will connect each end of the pallet to the adapter end plates. Shimming may be accomplished as required to establish the required dimension and flatness between the frame to end plates and end plates to standoffs.

The standoffs which interface with the pallet will be duplicates of flight hardware, but the side that interfaces with the adapter end plate will have oversized holes to accommodate any misalignment from tolerance buildup from one pallet to another.

PALLET/ADAPTER INTERFACE (HORIZONTAL) - LARGE SYSTEM



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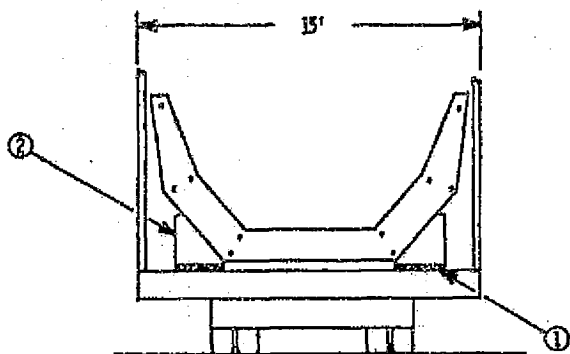
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PALLET/ADAPTER INTERFACE (VERTICAL) - LARGE SYSTEM

The adapter required to transport Spacelab pallets in the vertical position (as shown on the facing chart) is existing hardware provided by the Spacelab program and is included for reference only. The detail interface between the adapter and pallet is not available at this time, but should require no further definition as part of the transportation hardware development. Shock damping material must be provided between the adapter and the transport platform.

The large system can accommodate two pallets in the vertical position if the maximum payload height does not exceed 10.8 feet.

A two pallet train may be accommodated without separation if the maximum height restrictions are not exceeded and the length overhanging the ends of the pallet train does not exceed 4 inches on one end and 28 inches on the opposite end.



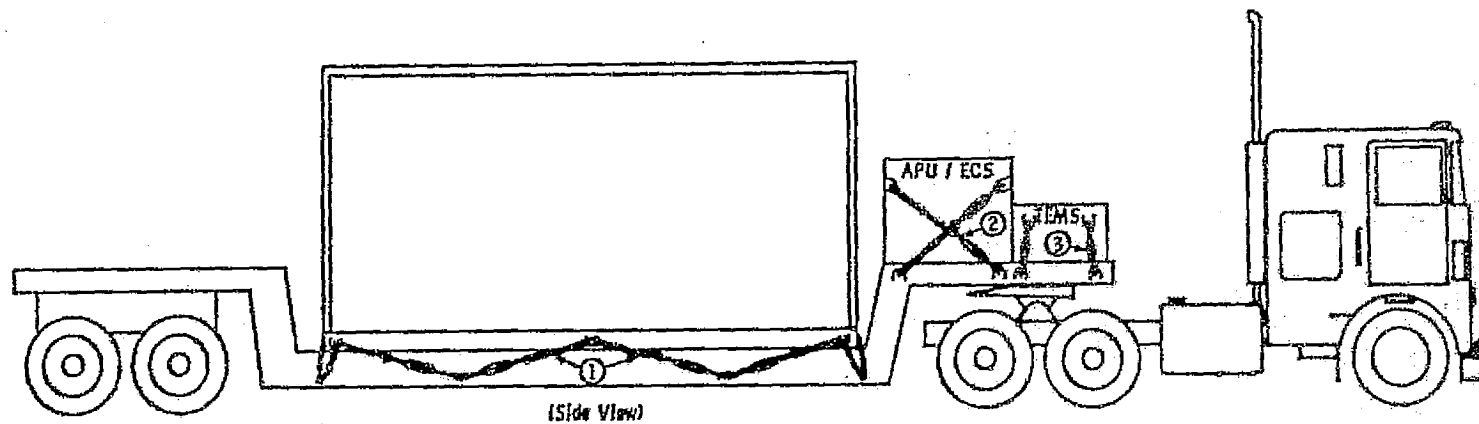
① Shock Isolation Material
② Existing ESRO GSE

CARRIER INTERFACE - LARGE SYSTEM

The carrier required to accommodate the large system is a 25-ton low boy, air-ride, tandem trailer and tractor. The trailer is 40 to 45 feet long with a drop section 23 feet long x 8 feet wide and a bed to ground height of 20 inches. The forward deck must have a platform at least 8 feet x 8 feet square capable of supporting a 5000 pound load. The carrier must have tie down rings on the sides of the bed. Adjustable sliding outriggers which could be extended to accommodate a 15 foot width are desirable but not mandatory in the drop section. The container to be transported is 11'10" high x 15' wide x 22'6" long, 16,000 lbs weight empty, TBD lbs loaded. The container will be secured to the carrier using 16 each, 3/4" turnbuckle/chain assemblies as shown on the facing chart.

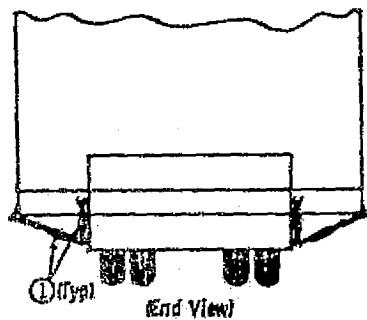
The hardware mounted on the trailer goose neck includes the APU/ECS, the TEMS and a container for spares, cables, tapes and test equipment. The APU/ECS is 48" high, 48" wide and 90" long and weighs approximately 2000 lbs. The TEMS is approximately 4' x 3' x 3' and weighs 300 lbs. The equipment box is presently undefined, but could use the remainder of the goose neck deck area, if required, which is approximately 3' x 5'. Each of these items will be secured to the carrier using turnbuckles or turnbuckle/chain assemblies.

The container lifting sling assembly must also be transported on the carrier. The disassembled sling assembly measures approximately 2' x 2' x 15' long and weighs about 1000 lbs.



TIE DOWN ASSEMBLIES

- ① Large Container - 16 Each
- ② APU / ECS - 8 Each
- ③ TENS - 4 Each



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ELECTRICAL INTERFACE - LARGE SYSTEM

The heart of the transportation system electrical system is the Auxiliary Power Unit (APU) which provides power to the following systems:

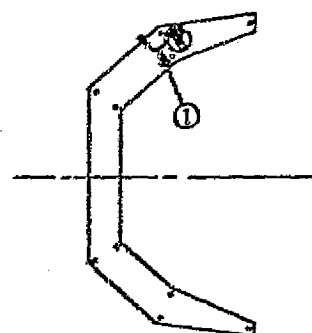
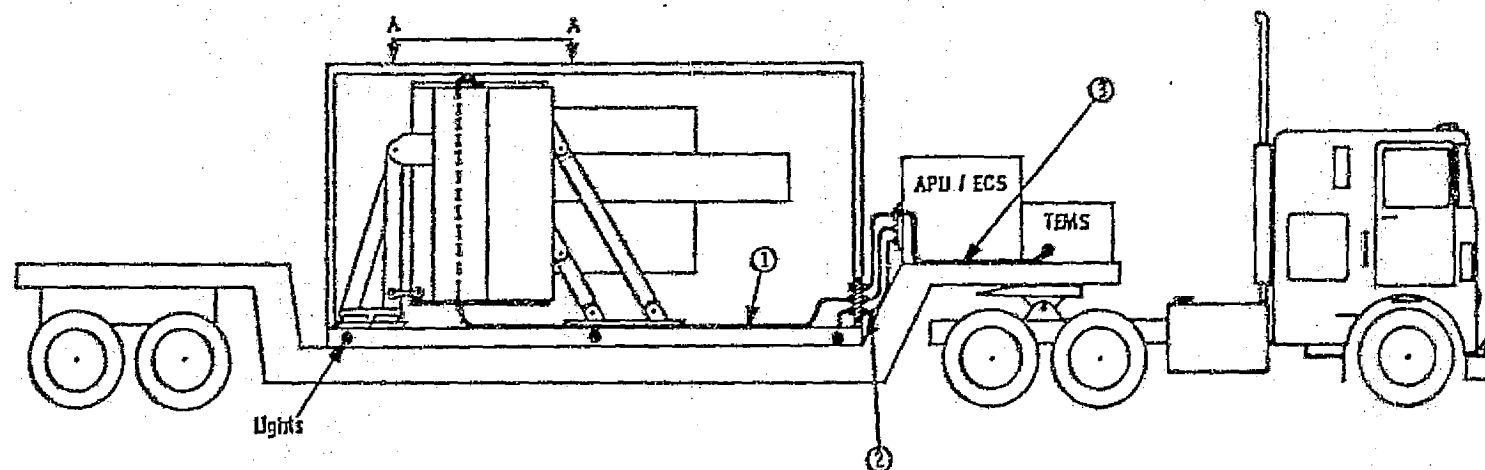
- Environmental Control Unit (ECU)	208 VAC, 3 Ø, 50/60 Hz
- Transportation Environmental Monitor System (TEMS)	28 VDC
- Payload service power	28 VDC
- Container clearance lights	28 VDC
- Service power	115 VAC, 50/60 Hz
- Storage battery (payload and TEMS)	28 VDC

The APU electrical interface panel will have connectors to provide power to the TEMS, payload and container. Cables will interface from the APU interface panel to the container interface panel and TEMS interface panel.

All connectors and cabling will be weather proof for both internal and external installations, in addition the internal cabling will be covered with special protection to prevent contamination to the spacecraft hardware.

The ECU can be operated from standard 208 VAC, 3 Ø, 50/60 Hz facility power if the APU is not operating.

The APU motor generator provides the 208 VAC, 3 Ø, 50/60 Hz and the 115 VAC, 50/60 Hz and drives a 28 VDC alternator to charge the 28 VDC batteries and provides 28 VDC operational power.



View "A-A"

- ① Payload Power - 28 VDC
- ② Container Clearance Lights - 28 VDC
- ③ TEMS Power - 28 VDC

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INSTRUMENT AND DATA INTERFACE - LARGE SYSTEM

The Transportation Environment Monitor System (TEMS) container is located on the front of the trailer deck next to the APU/ECU.

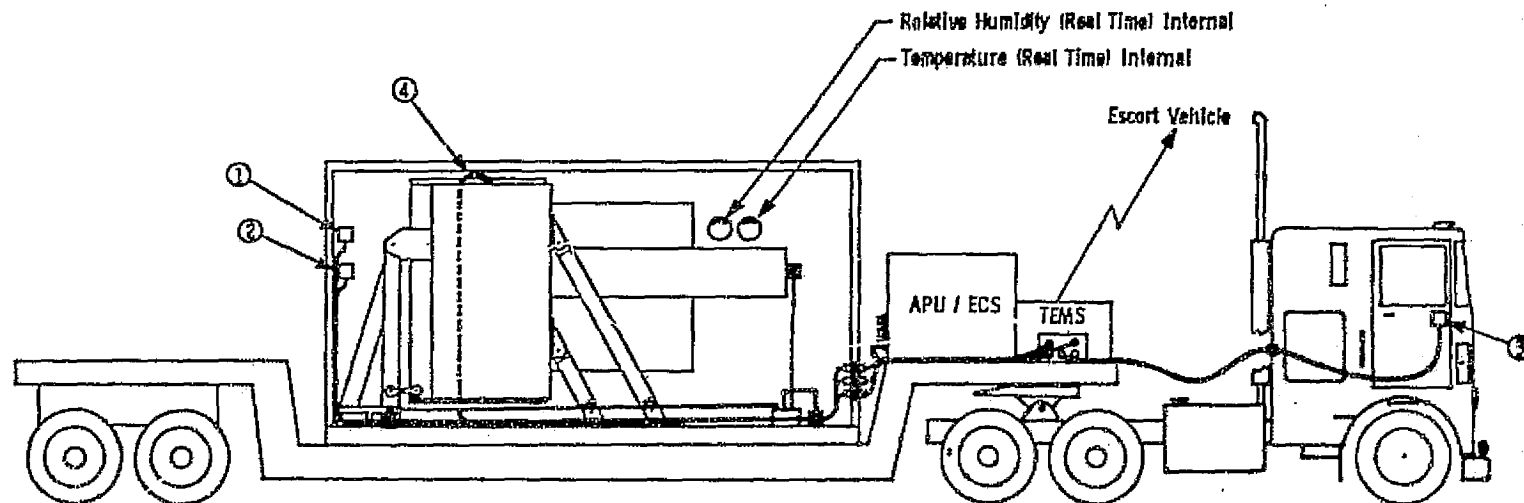
The TEMS container will interface from the electrical connections on the interface panel to the following:

- APU 28 VDC power output to TEMS
- Alarm indicator routed to the truck cab
- Container interface panel for 9 channels of accelerometer data
- Container interface panel for temperature and relative humidity
- Container interface panel for 28 VDC spacecraft power

The accelerometers will be mechanically attached to the container. The temperature and relative humidity sensors will be mounted on brackets and mechanically attached to the inside of the container cover as shown. All sensor cables will be permanently routed and clamped in position. When preparing to remove the container cover all cables must be disconnected from the inside of the interface panel.

The accelerometers will also be mechanically attached to the payload. Cables will be routed and secured to the container platform and connected to the interface panel. The spacecraft power will be monitored on the payload side of the payload interface panel.

Temperature and relative humidity gages are mounted on the outside of the container to provide real time data on the interior conditions.



■ Accelerometers (3 Each Triaxially Mounted at 3 Locations)

- ① Temperature Monitor
- ② Relative Humidity Monitor
- ③ Alarm Indicator (Audio/Visual)
- ④ Payload Power Monitor

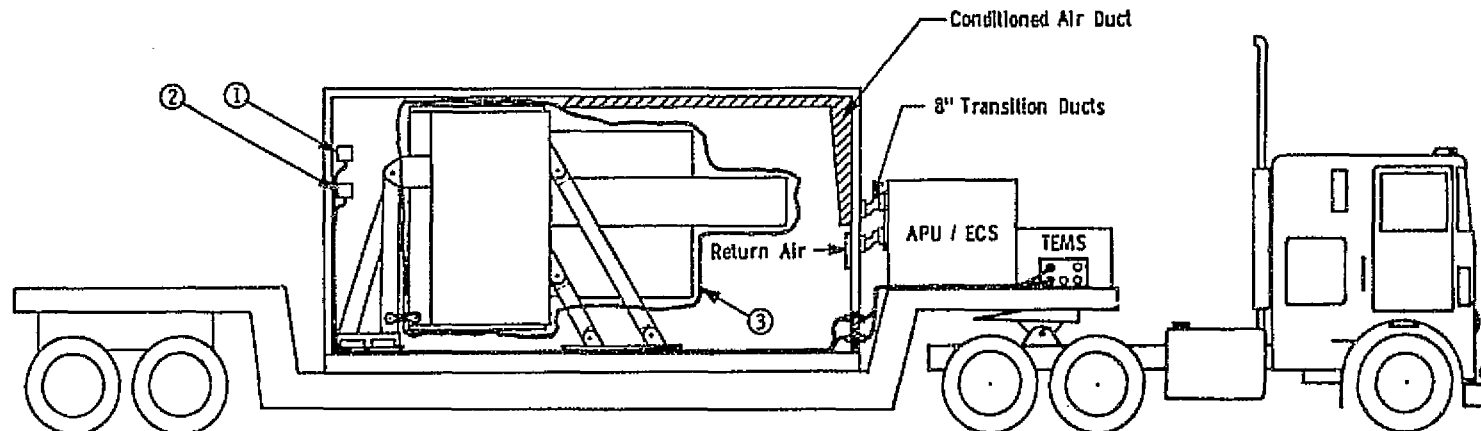
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ENVIRONMENTAL INTERFACE - LARGE SYSTEM

The APU/ECU is mounted as shown below with the air ducts facing the forward end of the container. Two each 8" transition flex ducts connect the conditioned and return air from the ECU to the container ducts. A removable air distribution duct is mounted inside the container.

Contamination control of the payload being transported is provided by enclosing the payload completely in a non-static producing clean bag prior to attaching to the payload adapter assembly. Air will be evacuated from the bag to allow it to cling to the surfaces prior to sealing it and after all instrumentation lines have been routed and function verified.

The TEMS will record the air temperature and relative humidity and will alarm out of tolerance conditions, but will not compensate the ECU to correct the condition.



- ① Temperature Monitor
- ② Relative Humidity Monitor
- ③ Anti-Static Plastic Bag to Control Payload Cleanliness

Capacity

- APU - 208 VAC 3 @ 50/60 Hz
 - 5KW Output
 - 115 VAC, 50/60 Hz
 - 28 VDC
- ECS - 24,000 BTU Cooling Cap
 - 4.5KW Heating Cap
 - 800 SCFM Air Flow
 - 40°F to +120°F Operating Range

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